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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 1000 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An *Honorary Member* shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

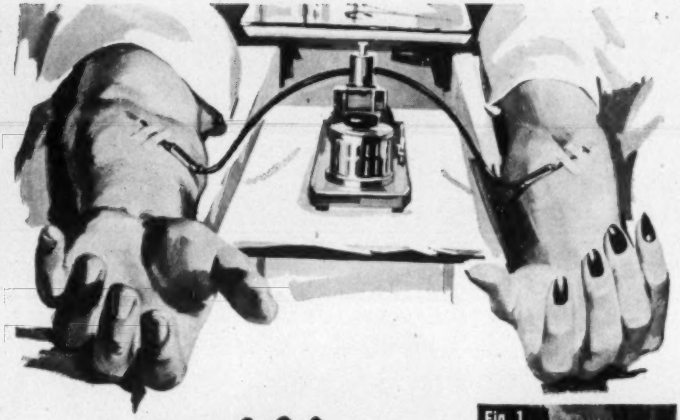
An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

Initiation Fees		*Annual Dues*	
Members	$ 5.00	Members	$ 5.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associate	25.00
Corporate Members	10.00	Corporate Members	15.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

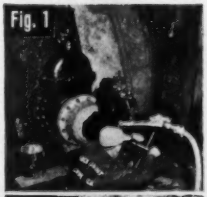


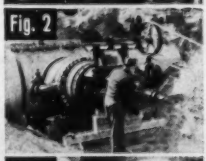
When a lifeline is tapped...

Tapping lifelines under pressure has become a vital technique for sustaining life and growth, whether it be a human circulatory system or a community water supply.

The method of tapping Lock Joint Concrete Pressure Pipe has been developed to a high degree of ease and efficiency. Of the thousands of taps made in various designs and sizes of this pipe, all have been effected with absolutely no damage to the structure of the pipeline.

Whether the job calls for a cross connection for a 150″ aqueduct (fig. 1), a 42″ outlet in a 60″ transmission main (fig. 2), or a ¾″ service connection in a 20″ transmission main (fig. 3), Lock Joint Concrete Pressure Pipe is tapped economically and with complete assurance.





LOCK JOINT
MADE ITS WAY BY THE WAY IT'S MADE
CONCRETE PIPE

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East Orange, New Jersey

Member of the AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION

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PIPE THAT SHOULDERS A HEAVY LOAD WITHOUT SHOWING ITS AGE

Recently installed in a town in Illinois, this cast iron pipe water supply system now serves a large industrial area.

Besides the internal pressure of supplying the heavy daily demand, there is a heavy load overhead, too. The industrial area is a packaging and distribution center. Large numbers of fully loaded rail cars and trucks come and go every day.

As far as the cast iron pipe is concerned, this is all in a day's work.

Cast iron pipe shoulders heavy loads —interior and exterior—year after year; performs efficiently for a century or more.

And it always delivers a full flow of water.

ADVERTISING CAMPAIGN FROM CAST IRON PIPE RESEARCH ASSOCIATION SHOULDERS A HEAVY LOAD, TOO!

For years the Cast Iron Pipe Research Association has attacked the water problem nationally; now, in addition, it is undertaking a new campaign to combat this crisis on a local level. Car cards, speeches, radio spots, newspaper ads, mailing pieces—everything will be included. If your town's problem is apathy or a growing water shortage, we may be able to help. For complete details, write to the Cast Iron Pipe Research Association today!

CAST IRON PIPE RESEARCH ASSOCIATION
Thos. F. Wolfe, Managing Director
3440 Prudential Plaza, Chicago 1, Illinois

CAST IRON PIPE
THE MARK OF THE 100-YEAR PIPE

COMPARED TO THE MONEY IT EARNS

Figure it this way:

Write down the revenue you earn each year from the average meter: $_____. Now multiply this by seven (the number of years many Commissions permit a meter to stay in service before retest) or by the number of years required by *your* local regulations.

What have you got? $_____. A figure somewhere in the neighborhood of $350 to $700? That's the money you entrust to just one water meter while your back is turned. That's the money it earns, twelve to twenty times its price.

Like any instrument, a meter runs slow as it wears, and gives water away before it is brought in for test and repair. Now if *one* meter, by virtue of better design and workmanship, stays accurate and brings in just 1% more revenue over the years, how many extra dollars is that worth to you? $3.50? $7.00?

That's how much more you could afford to pay for a Trident water meter.

There's extra value, too, in Trident's interchangeable design. New Trident parts fit old Trident meters. This "no obsolescence" feature insures automatic modernization, keeps repair costs down and protects your meter investment.

neptune
TRIDENT WATER METERS

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LIQUID METER DIVISION
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Neptune Meters, Ltd., 1430 Lakeshore Rd., Toronto 14, Ont. / Offices in Principal Cities

OLD FIRE HYDRANTS

STILL DOING 24-HOUR DUTY

IN CAMDEN, N.J.

The Camden, N.J., Water Department was formed in 1845, when James K. Polk was president. A small building was erected at the foot of Cooper Street to house the pumping station. Water mains were installed and approximately 15 years later, R. D. Wood Hydrants were tied in. Since those days Camden has grown from a community of 6500 people to a modern industrial city of 125,000. All utilities have been changed beyond recognition . . . except for a number of the original R. D. Wood Hydrants that are still in service. Conditions have changed, but the reliability built into those hydrants makes them just as effective now as they were over 100 years ago.

Like all R. D. Wood Hydrants, the oldtimers are of simple but sound construction; their operation cannot be impaired by foul weather, snow, sleet, ice or silt. Apart from the hazard of being in the path of a truck out of control or the possibility of street relocations, there is no foreseeable trouble ahead for them for many more years. There has never been better fire protection for any community than R. D. Wood Hydrants.

Conform to A.W.W.A. specifications

R. D. WOOD COMPANY

Public Ledger Bldg., Independence Square, Philadelphia 5, Pa.

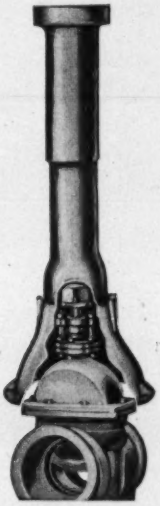
Established in 1803

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds)

2 Piece Sliding Type
Adjustable Valve Box

2 1/2 or 3 Inch
Heavy Duty
Service Box

2 1/2 Inch
Service Box



3 Piece Screw Type
Adjustable Valve Box

The Three "Bigs" in Buying

1. *Standardization*
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3. *Quick Delivery*

ESTABLISHED 1849

BINGHAM & TAYLOR

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CAST IRON SERVICE, VALVE, ROADWAY AND METER BOXES

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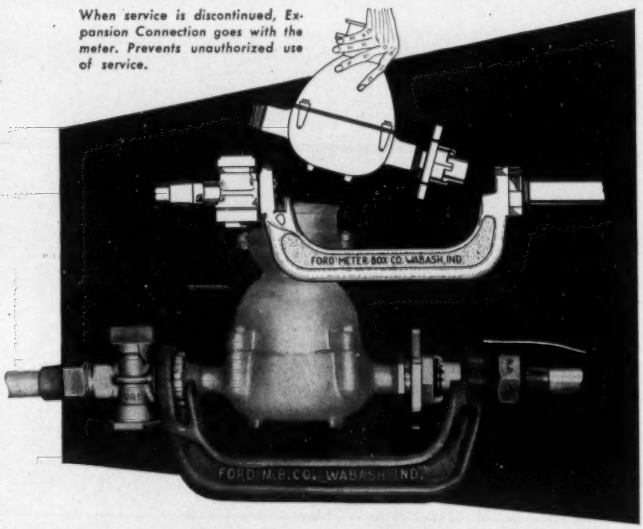
CULPEPER, VA.

When service is discontinued, Expansion Connection goes with the meter. Prevents unauthorized use of service.



THE FORD TWIST

that makes In-Line meters easy to change

Whenever meters are set in-line with service piping, especially in outside settings, they are notoriously difficult to get in or out. The Ford *twist* is a simple handwheel operated Expansion Connection on every Ford Straight Line Yoke. To begin with, the Ford Yoke holds both inlet and outlet piping rigidly in perfect alignment and with ample space to slip the meter in or out of position. Then, the Ford handwheel operated Expansion Connection fills the gap and automatically pressure seals both meter ends against rubber gaskets.

Millions of Ford Yokes already make meter servicing a pleasure. Are they doing it for your meter department?

Write for complete information on models available for every condition.

FORD for *better* water services

THE FORD METER BOX COMPANY, INC., Wabash, Indiana

MUELLER
for fast, easy service connections!

Only with "quality-matched" MUELLER Power Operated Tapping Machines, MUELLER Combined Drill and Tap Tools and MUELLER Corporation Stops can you be assured of a dependable, leakproof service connection.

Write for complete information and specifications.

MUELLER CO. DECATUR, ILL.

Factories at: Decatur, Chattanooga, Los Angeles In Canada: Mueller, Limited, Sarnia, Ontario

MUELLER CO. Since 1857 SERVING the Water-Gas Industries QUALITY

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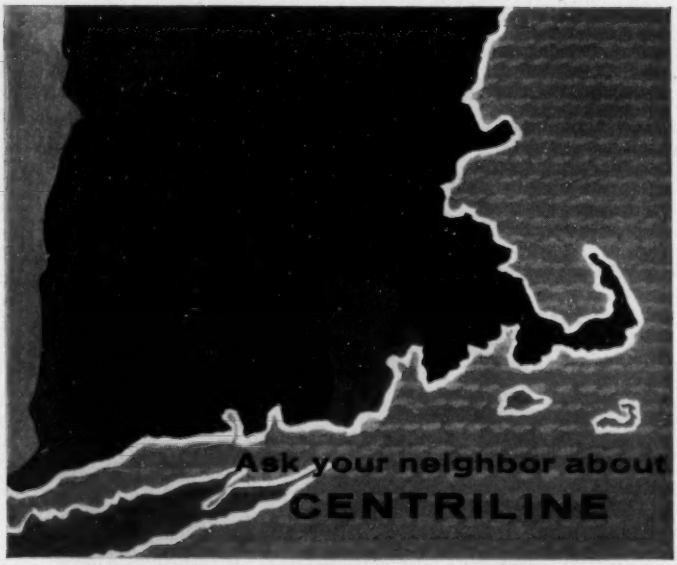

Spotted on this map are some of the places that have been served by the Centriline Process

Chances are that one of your colleagues has rejuvenated some of his city's piping by Centriline reconditioning. Here's your chance to find out.

Briefly, this process smoothly lines piping—**in place**—with cement-mortar, creating a pipe-within-a-pipe. This vastly increases carrying capacity, stops leakage, prevents corrosion and tuberculation, and prolongs pipe life indefinitely. Pressure goes up, pumping cost goes down, and there's no need to disturb traffic to replace mains. Over 6,000,000 feet of piping, from 4" to 144" diameter, have been treated by Centriline.

ASK YOUR NEIGHBOR

Write today for a list of nearby officials whose cities have cut inconvenience and costs with this pipe-saving process. Hear what they have to say about Centriline. Then write or call us. We'll be glad to show you how Centriline can help **you** solve the problems of pipe reconditioning in place.

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A Subsidiary of Raymond International Inc.

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Branch offices in principal cities of the United States, Canada, and Latin America.

very dependable

PATENTED SILICONE STUFFING BOX PACKING

a name to remember

WATCH DOG

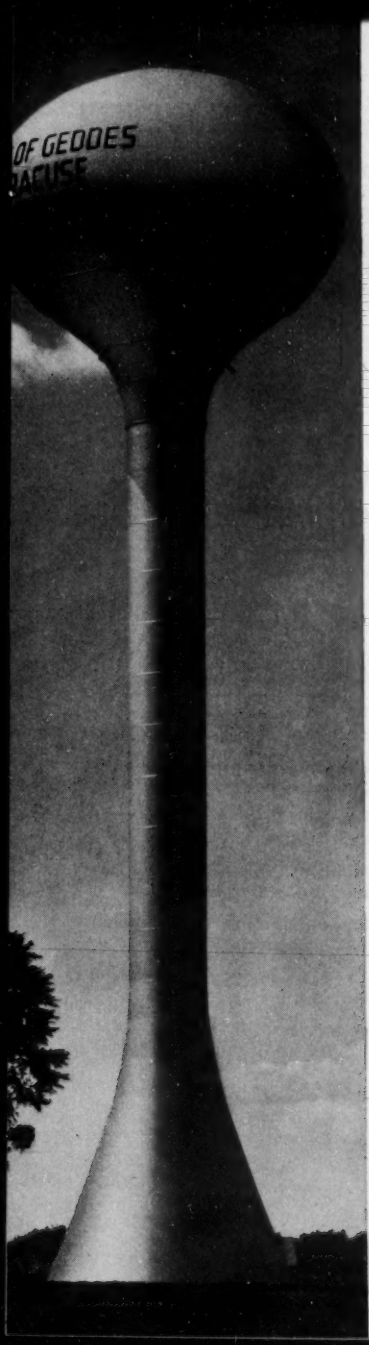
simple to maintain

Offices in principal cities

Split case or frost proof

GAMON METER DIVISION

NEWARK WORTHINGTON NEW JERSEY



why

Geddes, N. Y.

went

14 STORIES HIGH

to assure

better water service

for new industries

PDM
ELEVATED STEEL TANKS

PEDESTAL SPHEROID ELEVATED STEEL TANKS

This 147-foot PDM Pedestal Spheroid—world's highest tank of its type, so far as is known—brings a 500,000-gallon water capacity into balance with Geddes' expanding supply system. Serving the Syracuse industrial area with assurance of ample water facilities for new industries a-coming, the new PDM unit ties in with a 100,000-gallon tank 3 miles away for effective pressure equalization. Is *your* community preparing for increasing water demands?

Let a PDM representative work with you, at no obligation.

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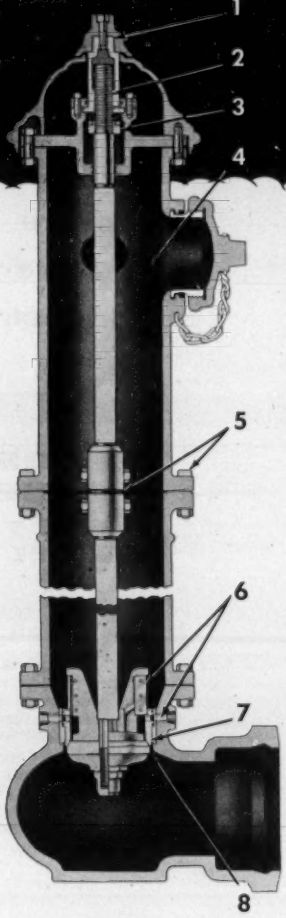
DENVER (2)	323 Railway Exchange Bldg.	
SEATTLE (1)	500 Wall Street	



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NEW!

SMITH MODEL H100 HYDRANT

proudly joins the time-proven Smith product line. No other hydrant has ALL these features:

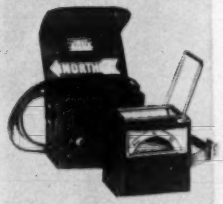
1. Weatherproof — Tamperproof Operating Nut.
2. Permanently Lubricated Operating Mechanism.
3. Top Travel Stop Nut Prevents Rod Bending.
4. Streamlined Openings Assure Maximum Delivery.
5. Frangible Bolts and Coupling Prevent Standpipe Damage.
6. Multiport Drain Mechanism Operates Automatically.
7. Bronze-to-Bronze Valve Assembly — Self-Sealed "O" Rings.
8. Compression Type Valve Prevents Flooding.

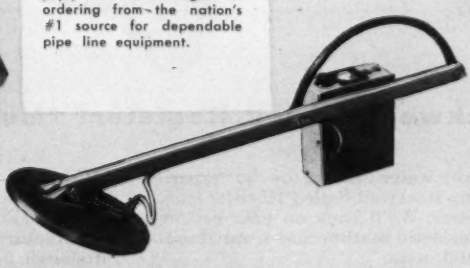
Write for details.

THE A.P. SMITH MFG CO.

HYDRANTS — VALVES — SINCE 1896

EAST ORANGE NEW JERSEY





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For ordering dependable and proven pipe line equipment, consult your latest Pollard Catalog #27.

Included in the #27 Catalog, and displayed on this page, are the M-Scope Transistorized Combination Leak Detector and Pipe Locator, Audio-Scope, Geophone Leak Detectors, T-10 Electronic Box Locator, Aqua Valve Box Locator and Magnetic Dipping Needles for locating service boxes.

Hundreds of water departments all over the country are using Pollard "one order" service. You, too, can enjoy the advantages of ordering from the nation's #1 source for dependable pipe line equipment.

PIPE LINE EQUIPMENT

JOSEPH G. POLLARD CO., INC.

PIPE LINE EQUIPMENT

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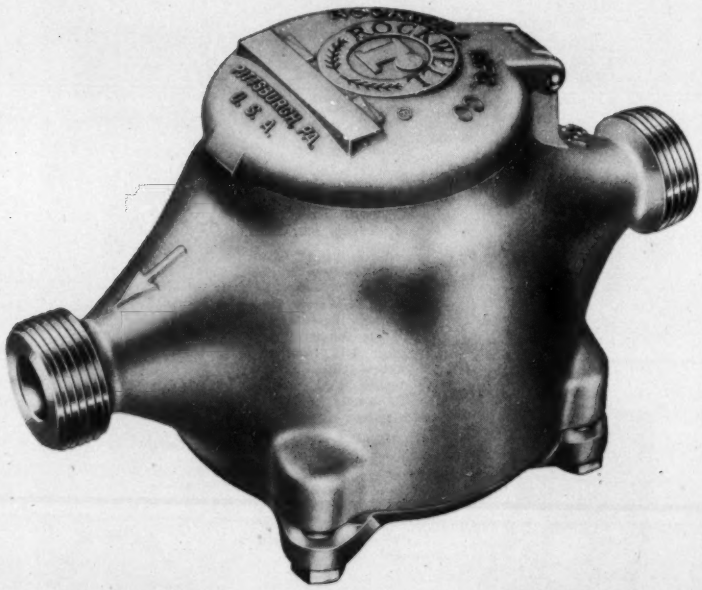
Ask the men who use them

(there are many in your area)



Rockwell Sealed Register* "Magnetic" meters

Ask nearby water utilities for *their* experience using Rockwell Sealed Register *magnetic* meters. We'll bank on your getting an enthusiastic testimonial from actual buyers and users.

Hundreds of thousands of these "magnetic" meters are now in service.

*Trade Mark

Please accept this challenge to "ask the men who use them." Write us and we will be glad to send you a list. Rockwell Manufacturing Company, Dept. 164C, Pittsburgh 8, Pa. In Canada: Rockwell Manufacturing Company of Canada, Ltd., Box 420, Guelph, Ontario.

Imitated, but never equalled!

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"Ah'm trainin' Oncle Rafe to swim under water... he wants to get a closer look at them boltless joints!"

U.S. cast iron PIPE

FOR WATER, SEWERAGE AND

another "first" from U.S. Pipe

Again, U.S. Pipe takes the lead . . .

This time with the new USIFLEX* Boltless Flexible Joint Pipe, specifically designed to cut costs, save installation time and labor on costly underwater jobs.

Developed after years of research . . . and exhaustive tests . . . Usiflex pipe takes to water like a duck. Marvelously simple to install. No bolts, nuts, wrenches. Self-sealing gasket and lead lock your only accessories. And Usiflex locks bottle-tight with only moderate thrust. Once locked, it stays locked . . . cannot be dislodged when assembled or deflected.

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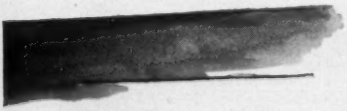
A Wholly Integrated Producer from Mines and Blast Furnaces to Finished Pipe.



USIFLEX
BOLTLESS FLEXIBLE JOINT* PIPE

*U.S. Patent No. 2,564,308

INDUSTRIAL SERVICE CAST IRON

1 Insert the gasket in its seat in the socket. Forming gasket loop helps initial stage of seating. Release of loop allows gasket to spring into the gasket seat where it is securely held.

2 Apply special Usiflex lubricant to the ball and inside surface of seated gasket in socket. After lubrication, ball is ready to be pushed into socket.

3 Ball has been socketed. Retainer ring lugs have been lined up with recesses in bell and retainer ring is ready to be moved into the bell and rotated.

4 After insertion and rotation of retainer ring in bell, the lugs on retainer ring are in back of and in register with internal flange segments in bell. Lead lock is partially inserted into recess between the bell and retainer ring.

5 Lead lock completely inserted in recess is being caulked in place by hammer blows on a wide caulking iron.

EDDY New Improved Products Meet Modern Needs

EDDY Fire Hydrant

- Improved, streamlined, modernized
- Optional break-flange
- Large diameter barrel
- New self-sealing main valve packing
- Requires no lubrication
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Completely new designs of horizontal swing check valves are available in sizes from 4 through 12 inches. They operate dependably in either vertical or horizontal positions and incorporate construction features which provide unusual flexibility of operation. These valves may be converted in the field from plain to single- or double-lever operation to meet changing requirements. Other check valves up to 24 inches.

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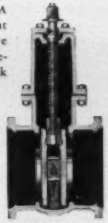
In addition to the regular line of EDDY Taper Seat AWWA gate valves, EDDY now offers a newly designed parallel seat AWWA gate valve in sizes through 12 inches. This valve has been specifically engineered to provide long, trouble-free service. Working parts are designed with heavy, thick section and large seating surfaces for dependable operation and improved wearing qualities. The valve has two-point, free-floating wedging for minimum friction and maximum operating ease. Other AWWA gate valves are available through 48 inches.



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Make your new or expanded water works system "pay off", not "pay out"! Don't risk plant obsolescence or equipment failure during the 20, 30 or 40 year life of the bond issue!

If you want reliable life-of-bond performance, specify B-I-F equipment . . . the most comprehensive, proven line of water works equipment. No other company can back its product line with so many successful municipal water works installations.

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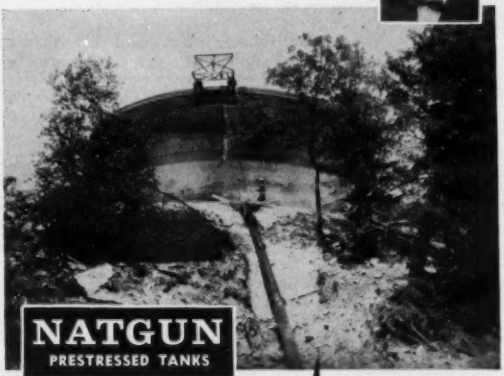

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PRESTRESSED TANKS

*"Milford answered its storage problem with the construction of a 500,000 NATGUN Prestressed Tank.

Construction began in the middle of April of 1960 and the tank was completed and in service during July of 1960.

After analysing and investigating various types of Storage Tanks, we felt the NATGUN Prestressed Tank best suited our needs, giving long years of service without costly maintenance and frequent interruption of service."

PRESTRESSED TANKS COST ONLY ONCE

100% MAINTENANCE-FREE

- NO RUSTING
- NO PAINTING
- NO DANGEROUS AND TROUBLE-SOME SHUTDOWNS

The story of how composite, wire-wound prestressed liquid storage tanks can effect substantial savings for you is worth knowing. For full information, write to NATGUN.

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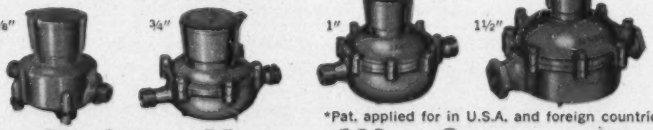

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1961

NEW ENGLAND WATER WORKS ASSOCIATION

ANNUAL CONVENTION

September 17-21

POLAND SPRING HOUSE

Poland Spring, Maine

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S. E. Burgen

KENNETH W. ROBIE

President of the New England Water Works Association
1960-1961

NEW ENGLAND WATER WORKS ASSOCIATION
ORGANIZED 1882

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This Association, as a body, is not responsible for the statements or opinions of any individual.

GHOSTS OF THE PAST; VISIONS OF THE FUTURE

BY E. SHERMAN CHASE*

[Read September 19, 1960.]

The past sires the present and the present sires the future. Over our shoulders the ghosts of our predecessors are looking and their spectral hands control our deeds for good or ill. As the past so is the present, as the present so will be the future.

During the centuries, truth and error have struggled, and good and evil have fought for supremacy. As truth and good prevailed, civilization and its works prospered. When error and evil dominated, civilization waned.

Back in the past of our water works profession is a long procession of men, many forgotten but others still remembered. The deeds and ideas of these men determined the practices of their times whether their ideas were good or bad. Where good those ideas have, in general, survived and are the basis for present practices. Where bad the ideas have, by and large, been forgotten although vestiges of some concepts continue to persist.

It is the purpose of this paper to recall some of those who in their time played important parts in the development of water works. In addition, practices and concepts long since discredited will be pointed out and progress made over the years will be indicated. Perhaps more stress will be given to the little known men and to those whose ideas were grossly in error, than to the well known whose contributions to our art and science are currently accepted.

Water works of sorts have existed for centuries in the Middle East, in Rome and various European countries. As *New* Englanders our interest in overseas developments is mainly

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with *Old* England and her men and practice in our field. For example, the first pumps (water power driven) to supply London with Thames River water were installed at the old London bridge by the Dutchman, Peter Morris, towards the end of the 16th Century during the reign of Elizabeth the First. For nearly 250 years pumps were maintained at London bridge, improved to be sure by successive engineers, but finally abandoned about 1822. The City Council, greatly pleased with this original installation, voted annual payments to Morris and his heirs and assigns for a thousand years. For nearly three centuries London continued these annual payments to the heirs and assigns of Peter Morris, long a ghost.

The well known Cornish pumping engine, the first of the steam pumps, was developed for dewatering tin mines in Cornwall. This pump was the work of Savery, a clockmaker and inventor of Devon and Newcomen, an ironmonger also of Devon. Some Newcomen engines were at work for over 200 years after their construction. Savery was the first to use the term horsepower to define the work done by his engine. The Cornish engine was later improved by James Watt and several were installed in the United States. Some years ago I saw a Newcomen pump at one of the London pumping stations that had been used for about a century.

With advances in engineering skills and knowledge the steam pumping engine became a highly developed and efficient tool of the water works industry. Its zenith of perfection was probably reached in the triple expansion crank and flywheel type developed during the latter part of the last century. The old, dignified, handsome pumps at the Chestnut Hill reservoir on the Boston supply are beautiful and romantic ghosts of a past era in pumping machinery. There is no beauty or romance, whatever their other virtues may be, in steam turbine or electrically operated centrifugals. Let us dismiss them from consideration.

The industrial revolution of the early 19th century had profound effects upon both water works and sewerage in both England and America, first in the former country. The increasing concentration of people in cities and industrial towns brought with it the need for sanitation and water supply. Recognition

of the need was slow in coming and action to meet the need was even slower. Pending action the toll of human lives resulting from filthy environments and impure water supplies was appalling.

Finer in his book "The Life and Times of Sir Edwin Chadwick" describes conditions existing in English towns in the middle of the last century. Of fifty large English towns only six had water supplies described as good whereas the supplies of thirty-one were supremely bad. In part of the city of Manchester 33 privies had to serve 7,095 persons, or one privy to 215 persons. Little wonder that accumulations of human excrement in back yards and alleys were too disgusting to describe. Street drains were not adequate to remove solids and in any event water closets were nonexistent. One of the incentives leading to the introduction of public water works was the need for adequate and continuous supplies of water for the carriage of human wastes and the flushing of drains used as sewers.

Finer writes "And in those sewers where there was enough water to wash the sewage to the outfalls, it would roll thickly and sluggishly until it slopped into the river whence the town's drinking water was drawn, unfiltered by the water companies that supplied it. Thick deposits settled at the bottom of the drinking glass. It was fortunate for the working classes that they possessed such a preference for beer."

In those days London was supplied by eight private water companies. Finer records competitive conditions between companies in 1839: "There were in some streets three distinct sets of pipes, with separate sets of persons to attend to each. Capricious customers were constantly changing from one to the other, and the pavement was torn up daily. The plumber's bills for removing the pipes from one main to another were, of course, enormous. So sharp was the practice, that sometimes the pipes were put to the wrong main, and one company sent in the bill for water which its opponent had unconsciously supplied.—The directors abused each other on paper, and the workmen actually fought in the streets."

The drawbacks to the use of then-existing drains were their shapes, alignment and grades which were such as to preclude

ready flushing. These defects were corrected by John Roe, an engineer to a sewer commission, who designed the egg-shaped sewer, and laid out sewers in straight lines and with adequate grades. For sewers to be effective, adequate supplies of flushing water were required whereas unreliable and intermittent delivery of water was the prevailing practice and water closets were practically unknown.

It was Thomas Hawksley, a water engineer who demonstrated the practicability of a constant supply of water, an essential for water carriage. Nevertheless much controversy took place over the adoption of pipe sewers and the removal of wastes by water. Strong sentiment was expressed for the dry earth closet instead of the water carriage system of human wastes. In spite of the controversy and in spite of technical disputes over design, pipe sewers became accepted and their adoption served as a stimulus for installation of improved water supplies.

The early history of water supply in New York City shows as unpropitious beginning as in London. In 1799, Aaron Burr founded the Manhattan Company, ostensibly to provide New York with a good and adequate water supply. However, his real purpose was to secure capital with which to found a bank, the Bank of Manhattan Company, and thereby gain financial sinews with which to fight Hamilton for political power. Neither Burr's water company nor his political career was successful.

Dayley writes "when he killed Hamilton in a duel in 1804, Aaron Burr was ruined once and for all. He had hoped to parlay 'pure and wholesome' water into making himself President, then emperor. No demagogue had ever used water as a weapon of conquest before, and Burr might have succeeded if his water had been of better quality. But the water which coursed through the wooden pipes was foul, and quenched the thirst of no man, least of all Aaron Burr."

As regards water quality, knowing what we now know, it seems unbelievable that eminent men of the later eighteen hundreds should hold some of the ideas they did about the hazards of sewage polluted waters. For example, Dr. Letheby, health officer of London, who died in 1870 in a statement relative to the Thames as a source of supply, had this to say: "I have

arrived at a very decided conclusion that sewage, when mixed with 20 times its volume of running water and has flowed a distance of 10 or 12 miles, is absolutely destroyed; the agents of destruction being infusorial animals, aquatic plants and fish, and chemical oxidation." This statement was made irrespective of the fact that London with its sewage polluted supplies from the Thames had 14,000 deaths from cholera in 1849; 10,000 in 1854; and 5,000 in 1866. When you realize that such a condition existed in England only 100 years ago and still exists in certain backward countries, you can appreciate the progress which has been made in one aspect of water supply practice.

In our own country Dr. C. F. Chandler, professor of chemistry at Columbia University approved in 1872 and again in 1885, the quality of the Hudson River at Albany as a source of water supply of that city only a few miles downstream from Troy whose sewers discharged raw sewage into the river. Furthermore, other cities up-state in the Hudson and Mohawk valleys contributed their share of sewage pollution. On the other hand the late Professor William P. Mason, a member of this Association and a contributor to its Journals took quite a different view, and in 1885 advised Albany to filter any supply taken from the Hudson. His advice was not taken until 1899 and then only after a bitter controversy and much opposition. In the meantime, Albany suffered the usual fate of cities using unfiltered, polluted river waters, namely excessive incidence of typhoid and diarrhea among the residents.

Other American cities besides Albany prior to the start of this century were provided with grossly polluted supplies, notably Philadelphia, Pittsburgh, Chicago, St. Louis, Montreal and others. (I can well remember, while a student in the water chemistry course given by Ellen H. Richards at M.I.T., hearing her advise us if ever in St. Louis to drink its beer, not its water.) Probably the most effective means for the dissemination of typhoid was Niagara Falls, N.Y., then taking unfiltered water from the Niagara River below the sewers of Buffalo. In 1901 the city of Niagara Falls had a typhoid death rate of 144 per 100,000 population. How many other deaths throughout the country directly or indirectly could be traced among the thou-

sands and thousands of visitors to the Falls can only be imagined.

The past 60 years have shown such improvement in the safety of the water supplies of the United States and Canada that water-borne typhoid is so nearly extinct that a recent outbreak of less than 20 cases in the small city of Keene, N.H., attracted nation-wide attention. The prevention of water-borne typhoid is probably the greatest accomplishment of the water works profession since about the first of the century. The men who have been instrumental in bringing this about, directly or indirectly, are many. Among them are names well known in the New England Water Works Association; Sedgwick, Fuller, Hazen, R. S. Weston, particularly in the field of water sanitation and purification and in connection with experiment stations at Lawrence, Louisville, and New Orleans.

Enough of the past and its ghosts. What visions of the future can we dream of today? The safe quality of our water supplies in the United States and Canada now seems assured. It is necessary, however, to be on guard against dangers arising when new products of industry result in toxic wastes not now known which may add poisons to sources of water supply. The hazards due to radio-active wastes and to fall-out must be guarded against, although evidence of immediate danger is lacking.

The application of atomic energy to the pumping of water may see a revolution in the design of pumping stations similar to that when electrical energy replaced steam.

With the approaching time when readily available sources of water supply in certain sections of the country will have been fully utilized by municipalities and industry, and where additional water from far distant sources would be uneconomic, it may well be that population and industry will cease expanding in those sections. Proximity to sources of mineral and agricultural raw materials will become less important than water resources which are readily available for development. To some degree the conversion of salt water to fresh may become economical for limited use and where the cost of water is not a prime factor in production. However, I look for the time, not too far off, when

the water resources of the Eastern seaboard will be as attractive to industry as nearness to mines or to other natural resources. The same attraction may hold true in case of the valleys of the Northwest, the Mississippi, and the St. Lawrence.

Referring again to the limited supply of water it is obvious that the reduction of wastage will permit more effective conservation and utilization of those supplies of limited quantity. This would necessitate an earnest and effective campaign to prevent willful or careless waste of water for which the consuming public is responsible. One means to accomplish this would be the establishment of maximum permissive use dependent upon real needs of the user. Maximum speed limits are established on our highways even though the cars are powerful enough to far exceed these limits.

One needed reform to help achieve this end is the improvement of interior plumbing to reduce leakage and wastage. Industrial wastage is particularly serious. Two measures to reduce such wastes would be; first, a financial penalty for excessive use; and second, a sewer service charge based on water consumption. Water is now too cheap. Unquestionably these two measures would arouse a storm of protest such as proposals to introduce universal metering have provoked. Maybe waterless days once a year would be effective in waking up the public to their dependence upon water. One program which will unquestionably be widely undertaken in the future is the restoration of the carrying capacity of cast-iron pipe distribution systems by cleaning and interior coating in place. Some day someone will develop a particular kind of plastic material and a method of its application, which will permit economic rehabilitation of thousands of miles of old distribution pipes.

In the field of water purification the semi-automatic filter plant is now a reality as in Philadelphia. More progress along this line will undoubtedly occur. The same is true of micro-wave transmission of remote data and automatic control of gates and pumps, also as exemplified in Philadelphia. Automation must be used with judgment. Common sense will never go out of fashion.

As in the building industry the production of new materials in the water works industry will surely result in changes in prac-

tice. Plastic types of service pipe, corrosion-proof, will be used more and more as materials and fittings are improved. Metallurgical findings which will better older materials like steel, iron, and brass, will enhance their value and keep them in competition with the newer materials.

One vision which may well become a reality, when the world is less tumultuous than it now is, will be the introduction of adequate and safe supplies in the backward areas. Presently, conditions in certain far-Eastern countries are reminiscent of those described by Finer as previously quoted.

In the more advanced countries progress in the art and science of water supply and water works is inevitable. What precise lines this progress will follow, other than the few briefly outlined herein, are conjectural. One thing is sure, however, we can look forward to a more acute awareness on the part of the public of the indispensable role played by the water works profession. Let us continue to follow that profession with diligence and pride that we may be worthy of our heritage and make reality of our visions.

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GROUND-WATER RESOURCES IN THE MATTAPOISETT RIVER VALLEY

BY CLARENCE I. STERLING, JR.*

[*Read September 20, 1960.*]

A study was recently made by the Massachusetts Water Resources Commission in cooperation with the Ground Water Branch of the U. S. Geological Survey of the ground water resources of the Mattapoisett River Valley. This is a small drainage area containing about 24 square miles extending from tidewater to the headwaters in Snipatuit Pond. The drainage area is located principally in the towns of Rochester and Mattapoisett and the river empties into Buzzards Bay about five miles east of the city of New Bedford. The study was done as a part of the general ground water resources investigation being made by the Commission in Plymouth and Bristol Counties.

At the present time, the town of Mattapoisett obtains all of its water supply from three different well installations in the Mattapoisett River Valley. In addition, the Fairhaven Water Company has installed two groups of wells in the same valley from which they obtain about ¾ of the water the Company supplies to the town of Fairhaven (see Figure 1).

The town of Marion obtains its water from wells located both in the towns of Marion and Rochester, but outside of the Mattapoisett River Valley. There is no public water supply in the town of Rochester, but some of the residents are supplied with water from the Marion system.

In 1958 the town of Marion wanted to develop additional sources of water and filed legislation (Senate Bill 583) which would permit that town to develop additional wells in a new area in Rochester, principally in the Mattapoisett River Valley. This legislation was opposed by the other towns on the basis that there might not be sufficient ground water available in that

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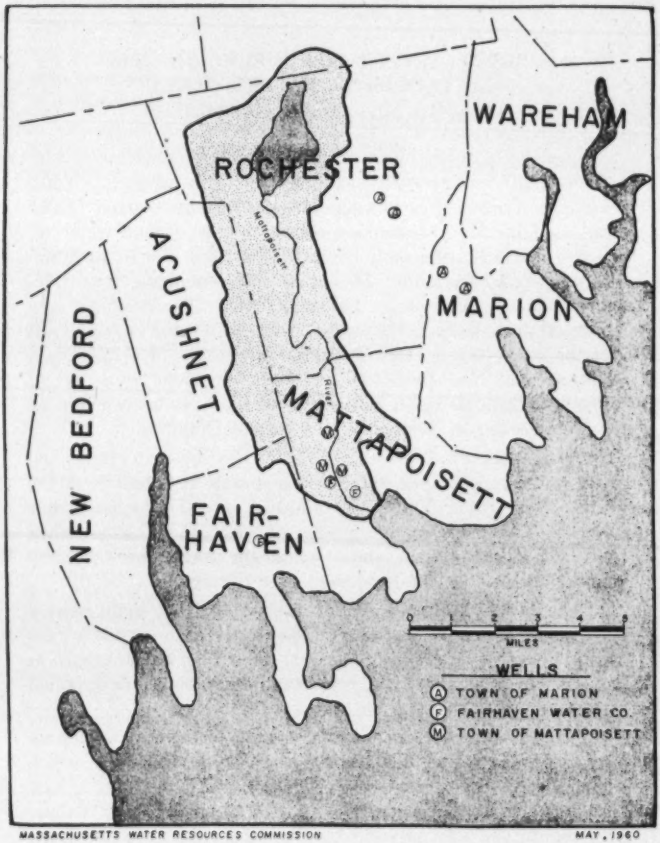
WAREHAM
ROCHESTER
MARION
ACUSHNET
NEW BEDFORD
MATTAPOISETT
FAIR-
HAVEN
0 1 2 3 4 5
MILES
WELLS
A TOWN OF MARION
F FAIRHAVEN WATER CO.
M TOWN OF MATTAPOISETT
MASSACHUSETTS WATER RESOURCES COMMISSION
MAY, 1960

FIG. 1

valley to take care of more than the needs of Mattapoisett and Fairhaven. For this reason, the Water Resources Commission made this study to ascertain if there was ample water to serve the four towns involved.

The surface geology and ground water study was made by the Ground Water Branch of the U. S. Geological Survey under the cooperative agreement that the Commission has with that agency. Two temporary stream gaging stations were established on the Mattapoisett River by the Surface Water Branch of the U. S. Geological Survey to measure stream flows. The seismic work was done by the Weston Geophysical Engineers under a contract with this Commission.

In addition, the staff members of the Commission worked with all three of the above organizations in coordinating the activities of the study. The study was made between June 1st and November 30, 1959.

The northerly watershed divide is poorly defined as Snipatuit Brook connects Great Quittacas Pond with Snipatuit Pond. At times this brook flows northerly into Great Quittacas Pond, which is in the Taunton River drainage area, and at other times flows south into Snipatuit Pond. Great Quittacas Pond is a source of water supply for the City of New Bedford so that the direction of the flow depends upon the relative water level in the two ponds.

There is nothing unusual about the way the basic data was obtained for the area, viz:

a) The flow of the Mattapoisett River was recorded by the installation of two temporary stream gaging stations.

b) Data was obtained in regard to all existing wells in the area.

c) Rainfall records were kept during the period of the study.

d) Record was made of the amount of water that was pumped out of the drainage area for water supply purposes by the Town of Mattapoisett and the Fairhaven Water Company.

e) Ground water levels were measured by recording devices or by periodic measurements.

f) Seismic studies were made at various cross sections across the river valley to determine the depth of bedrock.

g) A field study was made of the surficial geology of the area.

A study was made of the population and water consumption increases for the period from 1940 to 1955 which included the World War II and post-war years. The three towns principally involved in the water supply problem, Fairhaven, Marion and Mattapoisett, all have large increases in their summer population. However, the rate of increase of the permanent population of the three towns is much less that the increase in per capita water consumption for the same period. The comparison of the increases is shown in the following table:

Town	*Population*	*Water-consumption increase*
Fairhaven	22%	204%
Marion	37%	178%
Mattapoisett	65%	192%

The rainfall measurements as recorded at the Rochester rain gage were 13% above normal for the year 1959 and 13% above normal during the study period from June 1 to November 30, 1959.

As stated before, the stream flow of the Mattapoisett River was measured at two locations. There are two ponds in the drainage area which influence the ground water storage in the valley and the stream flows. Hartley Mill Pond is artificially regulated so it was therefore decided to install a temporary stream gaging station of the recording type below that pond to determine the effect of regulation on the stream flows. A second gaging station was located opposite the upper well field of the Fairhaven Water Company. The net drainage area between the two stations was 10 square miles.

An attempt was made to coordinate the stream flow records of the Mattapoisett River with the records of the Adamsville Brook gaging station in Adamsville, Rhode Island, where long-

term records are available. Adamsville Brook has a drainage area of 8.6 square miles.

A comparison of the flows for the two drainage areas is shown by months in the following table:

	Average daily flow (c f s per sq mi)	
Month, 1959	*Mattapoisett River*	*Adamsville Brook*
June	2.03	1.73
July	1.93	2.00
August	0.355	0.343
September	0.160	0.057
October	0.319	0.243
November	1.37	1.33

It can be seen that the flows of the two drainage areas are similar except during periods of low flow, when apparently the yield of the Mattapoisett River drainage area is greater. This is undoubtedly due to geological conditions which permit the flow of groundwater into the stream from ground water storage during the drier periods.

A study was made of the present and future water needs in relation to the availability of groundwater in the area.

The study did show that, even though it was made during a period of excess rainfall, the surface and ground water yields are inter-related in the Mattapoisett River Valley so that the basin acts as a single unit insofar as water resources are concerned.

It is conservatively estimated that about five and a half million gallons per day of underground water can be taken from this drainage area with proper development during a dry period such as was experienced in the summer of 1957. This compares favorably with the estimated future water needs of the four towns involved, including Rochester, when a water system is installed in that town.

The water consumption for these towns in 1959 was slightly less than 2.0 million gallons per day, the estimated consumption for 1980 is slightly over 3.4 million gallons per day, while the estimated consumption for the year 2000 would be slightly in

excess of 4.6 million gallons per day. Thus, there would be sufficient water supply for the needs of the four towns involved at least up to the end of the century, not counting the sources of supply that two of the towns now have outside of the valley.

Figure 2 shows the relationship between water needs and availability.

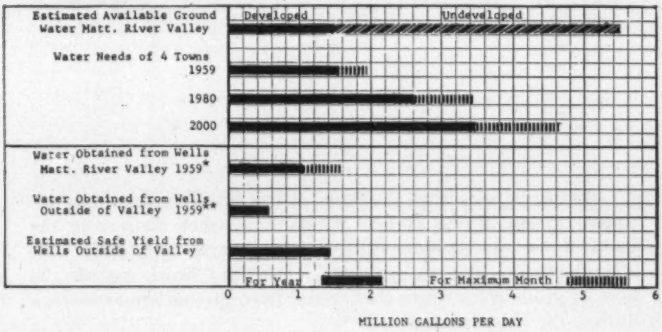

FIG. 2

There should be an integrated plan for developing new sources to insure maximum development without interference. Possibly a joint water board could be created with representation from the four towns to be responsible for developing and operating the source of water within the basin. The individual town water departments would continue to retail water from their own distribution systems.

One of the most interesting things insofar as this survey is concerned was the development of a map for presentation of the data in a form that could be readily understood by engineers, water department officials, and other persons who may not have special training in the field of geology. The map (Plate I) contains a description of the geological units, indicates by color* the

*Because of the prohibitive cost of reproducing a map in several colors, the more favorable soils are indicated by shading.—ED.

Massachusetts
WATER RESOURCES COMMISSION

in cooperation with the

U. S. GEOLOGICAL SURVEY

Ground-water Areas

Areas in which wells properly located (as by test drilling) and properly constructed may be expected to yield amounts of water within the limit specified. These limits are approximations; they are estimated on the basis of the best geologic and hydrologic data available. The map does not indicate the total quantity of ground water that may be withdrawn perennially from any given area or ground-water reservoir; determinations of total quantity generally can be made only on the basis of special investigations of particular areas.

To be properly located, wells in the two areas of higher yield should be placed where saturated permeable materials are relatively thick. The bedrock-contour map, when used in conjunction with the general rules for estimating the level of the water table given below in the explanations of the ground-water areas, serves as a guide to the thicker saturated materials. An average of about 10 feet of till, which is relatively impermeable, overlies the bedrock surface, and estimates of the saturated thickness of permeable materials should be adjusted accordingly.

	B 0	**Less than 10 g.p.m.**

Water is obtained from glacial till or from the underlying bedrock. Wells in bedrock generally are more dependable than wells in till, which may fail during times of drought.

	10-40 g.p.m.

Water is obtained principally from sand and gravel in kame, kame-terrace, and end-moraine deposits and ice-channel fillings. The saturated zone in these features is thin, generally less than 20 feet. The water level in swamps, ponds, or streams adjacent to these features is a rough guide to the level of the water table. Where wells can be situated so as to induce recharge from surface-water bodies, it may be possible to obtain quantities of water larger than the upper limit specified.

	More than 40 g.p.m.

Water is obtained principally from sand and gravel in outwash plain and valley-train deposits and some ice-channel fillings. The maximum yield of a well reported in this area is 450 gpm. The valley train is traversed by the Mattapoisett River, and large sustained yields may be obtained from wells situated so as to induce recharge from the river. The river level is a rough guide to the level of the water table in the valley train deposits. A rough guide to the level of the water table in the out-wash is the water level in adjacent swamps, ponds, or streams.

Surficial Geologic Units

Recent	Qs	SWAMP DEPOSITS Carbonaceous sand, peat, and organic matter.
		Ice-laid Deposits (CONTEMPORANEOUS IN PART)
Pleistocene Wisconsin Stage	Qgm	GROUND-MORAINE DEPOSITS An uneven, discontinuous blanket of till (an unstratified poorly sorted compact mixture of clay, sand, gravel, and boulders) forming a gently undulating surface.
	Qd	DRUMLIN Elongate hills of till.
	Qem	END MORAINE A hummocky kettled ridgelike form composed of till interspersed with lenses and layers of stratified sand and gravel; an ice-marginal feature constructed before a stable ice front.
	Qft	FLOWTILL Lenses of till overlying or interstratified with sand and gravel; probably represent superglacial mudflows. Indicated by arrow where too small to be mapped as a separate unit.
		Water-laid Deposits (CONTEMPORANEOUS IN PART)
	Qk	KAME OR KAME-PLAIN DEPOSITS Knobby steep-sided hills of stratified sand and gravel; formed in contact with glacial ice.
	Qic	ICE-CHANNEL FILLING Long, narrow ridges of generally medium to coarse gravel and some sand; formed in channels in or beneath the ice. (Includes forms known as eskers and crevasse fillings)
	Qkt	KAME TERRACE DEPOSITS Terracelike forms of stratified sand and gravel deposited between glacier and valley wall.
		OUTWASH-PLAIN DEPOSITS

Quaternary

A rough guide to the ... swamps, ponds, or streams.

Surficial Geologic Units

Recent	Qs	SWAMP DEPOSITS Carbonaceous sand, peat, and organic matter.
		Ice-laid Deposits (CONTEMPORANEOUS IN PART)
Wisconsin Stage Pleistocene	Qgm	GROUND-MORAINE DEPOSITS An uneven, discontinuous blanket of till (an unstratified poorly sorted compact mixture of clay, sand, gravel, and boulders) forming a gently undulating surface.
	Qd	DRUMLIN Elongate hills of till.
	Qem	END MORAINE A hummocky kettled ridgelike form composed of till interspersed with lenses and layers of stratified sand and gravel; an ice-marginal feature constructed before a stable ice front.
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	Qkt	KAME TERRACE DEPOSITS Terracelike forms of stratified sand and gravel deposited between glacier and valley wall.
	Qow	OUTWASH-PLAIN DEPOSITS Plains underlain by stratified sand and gravel deposited beyond the glacier by melt-water streams.
	Qou	UNDIFFERENTIATED OUTWASH Deposits of outwash sand and gravel whose landforms are not distinct enough to classify.
	Qvt	VALLEY-TRAIN DEPOSITS A long, narrow deposit of outwash material confined within a valley; deposited beyond the glacier by melt-water streams.
Quaternary / Early Paleozoic(?)		DEDHAM GRANODIORITE Ruled pattern indicates areas of bedrock covered in places by thin surficial deposits.

Explanation

- Drainage-basin boundary
- Axis of bedrock valley
- Contour — Showing approximate altitude of bedrock surface. Contour interval is 20 feet; datum is mean sea level. A negative sign (—) before a contour number indicates feet below mean sea level.
- Seismic survey line
- ★ Mattapoisett water supply
- ○ Fairhaven water supply
- Sand & gravel pit
- Well
- Test hole drilled to refusal
- Stream-gaging station
- Well with continuous water-level recording meter

CONTOUR INTERVAL 10 FEET — DATUM IS MEAN SEA LEVEL

SCALE 1:24000

Clarence I. Sterling, Jr., Director & Chief Engineer, M.W.R.C.
Geologic mapping by Charles E. Shaw, Jr., U.S.G.S.-1959
Map prepared by William M. Everberg, M.W.R.C.

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PLATE I.—MATTAPOISETT RIVER BASIN, MASSACHUSETTS
BEDROCK CONTOUR AND PRELIMINARY SURFICIAL GEOLOGIC MAP SHOWING GROUND-WATER AREAS

more favorable soils for obtaining groundwater, and indicates the depth of bedrock in relation to surface topography. A person using the map would not have to read the detailed geological report in order to know the favorable locations for new sources of water. If one were to determine where the depth of favorable material was above bedrock, he would then note from the map that the green color indicates the more favorable sites for water, while the brownish color indicates areas that are not favorable for securing large quantities of ground water. The lighter the shade in each color classification, the more favorable the condition for that particular type of soil.

If the limitations of the use of the maps of this type are understood, maps of this type can be very valuable in our water resource development. The principle limitation to keep in mind is that, while the colors on the map are sharply defined, in reality in many cases there is a graduation of soil conditions between the favorable and unfavorable soils.

In looking for a ground water supply one would avoid the brownish shaded areas but would drive test wells in the green shaded areas. This still wouldn't guarantee, however, that a large quantity of water would be readily available. As you know, there is great variation in the underground geology in our New England area.

We hope that maps of this type can be made of all of the Massachusetts river valleys. We can only do it with the support of the water works officials, consulting engineers, and other persons interested in our water problems to see that we secure sufficient appropriations not only to make the surveys but to be able to publish the results.

The writer wishes to acknowledge the fine cooperation of Mr. Charles Shaw, Jr., and Mr. Richard G. Petersen, who made the geological field surveys, and Mr. Milton O. Hackett, District Geologist, of the Ground Water Branch, and Mr. Charles Knox of the Surface Water Branch, of the U. S. Geological Survey for their enthusiastic interest.

THE ONTARIO PLAN IN THE ADMINISTRATION OF WATER RESOURCES

BY DR. A. E. BERRY*

[*Read September 20, 1960.*]

The Province of Ontario has embarked on a new and unique program on Water Resources. Legislation was enacted in 1956 and added to in later years. The main feature of this was the creation of a Water Resources Commission with wide authority to deal with problems of water supply, sewage and industrial waste disposal, and all related matters. This program has now been in full operation for more than three years, and it is possible to examine the results and to draw conclusions on the accomplishments.

By the adoption of this program the Province recognized the important role played by water resources in the development and orderly progress of the Country. The situation preceding this action pointed clearly to the marked requirements of the Province for adequate water supply for all areas in which growth was to be encouraged. It was clear that water resources must be conserved against the ravages of pollution from sewage, industrial wastes, and other substances which might impair the quality of water and interfere with its repeated use. The relationship between water supply and pollution was made clear by the over-all objectives of the Commission.

This new program resulted from a number of factors which had been developing over a period of time. A better understanding of this action may be had through an analysis of some of the conditions which brought about this change in policy. Ontario has a population of over six million. It covers an area of 412,582 square miles, out of a total of 3,845,794 square miles for all Canada. The scattered distribution of population creates problems where community projects are involved. Southern Ontario has the highest concentration of population and has

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been a focal point for industrial growth. Opportunities for this continued growth are great, but the problems associated with this also are great.

It is well recognized that growth and human betterment cannot be sustained unless adequate water supplies are available. These are among the greatest of national assets, and the quality must be protected at all costs. The importance of the Great Lakes system to southern Ontario is clearly evident. Large communities and industries have been attracted to these waters over a period of many years. Now as the growth moves inland, the adequacy of water and the prevention of pollution take on new significance.

Inland communities in much of Southern Ontario were faced with water problems, including quantity, quality and pollution control. Rapid run-off and resulting low stream flows in the summer months combined to make pollution a serious problem when these watercourses were needed to serve their normal functions. Costs for the development and transportation of water had risen sharply, and high interest rates had added further to this difficulty. It became even more essential to protect local water supplies from pollution when the expenditures for other supplies were so great. When water must be piped long distances, or when the most economical arrangement is necessary in sewage and waste disposal, there is an advantage in dealing with these on a regional basis for a number of municipalities rather than having each attempt to solve its own problems separately. Individual efforts in the past have not led to the most effective solutions.

By 1955, the need for water supply and sewage treatment works was sufficiently urgent to call for action at the Provincial level. This was especially true in southern Ontario, where a major post-war growth had been experienced, and where there was every promise of a continuance of this expansion if no serious restrictions or barriers were placed in the way. Adequate water resources of good quality were recognized as a primary need for insuring this continued growth and the welfare of the Province. It was fortunate that the interrelationship of waste disposal and availability of water supplies was conceded in the program to be adopted by the Province.

Action by the Government

These adverse conditions which might develop in relation to water resources were foreseen by the Government of the Province, and a Water Resources and Supply Committee was appointed in 1955 to inquire into and to advise on a constructive program. The Committee consisted of five members under the chairmanship of Mr. A. M. Snider. The Committee's report of that same year was followed immediately by legislation, made effective in April of 1956, and through which a Water Resources Commission was appointed, consisting of five men under the same Chairman. This first legislative enactment authorized the development of an organization and necessary procedures for carrying out the program. This bill was considerably altered in April of 1957 under the title, "The Ontario Water Resources Commission Act, 1957." Some further amendments were made in each subsequent year. These various actions provided the means for the Commission to proceed aggressively on its objectives.

The Ontario Water Resources Act

The broad scope of the authority given to the Commission is set out in Section 16 of The Ontario Water Resources Commission Act, which reads as follows:

"Notwithstanding any other Act, it is the function of the Commission and it has power,

"(a) to control and regulate the collection, production, treatment, storage, transmission, distribution and use of water for public purposes and to make orders with respect thereto;

"(b) to construct, acquire, provide, operate and maintain water works and to develop and make available supplies of water to municipalities and persons;

"(c) to construct, acquire, provide, operate and maintain sewage works and to receive, treat and dispose of sewage delivered by municipalities and persons;

"(d) to make agreements with any one or more municipalities or persons with respect to a supply of water or the reception, treatment and disposal of sewage;

"(e) to conduct research programs and to prepare statistics for its purposes; and

"(f) to perform such other functions or discharge such other duties as may be assigned to it from time to time by the Lieutenant-Governor in Council. 1957, c. 88, s. 16."

In addition to the preceding the Act contains authority for regulations to be adopted for—"regulating and controlling the use of water from any source of supply."

The major features of this legislation may be considered under two parts, one dealing with the supervision by the Commission over all water and sewage works in the Province; the other having to do with the construction of water and sewage projects by the Commission for municipalities and others. Some features of these two parts of the program may be of interest at this time.

For many years the Ontario Department of Health under public health legislation had exercised supervision over public water and sewage works built and maintained by municipalities or persons. This was similar to what was done in other provinces of Canada and in most of the States. Under The Water Resources Commission Act, the clauses contained in The Public Health Act were not only transferred to the Commission, but were considerably expanded and altered to permit more effective control. This was especially so in relation to stream pollution.

This new program for water and sewage works construction is a distinct departure from the procedures of the past. It is believed to be also different from practices followed in other countries. The object was to help municipalities meet their demands for these utilities. The Commission offers financial advantages as well as expert technical assistance in the planning, construction, and operation of the works. This procedure obviates the need of the municipality to issue any bonds or to borrow any money for the works.

Construction Procedures under the OWRC

The procedure followed by the Commission in its program of constructing these water and sewage projects has several new features not otherwise utilized in Ontario.

1. In the first place, any municipality is free to decide whether it wishes to do its own work, or whether it desires to place this under the Commission. The services of the Commission are available to any municipality, but there is no effort made to urge a municipality to place a project under the OWRC.

The chief desire of the Commission is to see that the work goes forward. If the municipality so requests it, an agreement can be made between the corporation and the Commission, under which the latter undertakes to design, build, finance, and operate the water or sewage project. A standard form of agreement is used, subject to minor alterations to meet local conditions. This agreement on a project may involve one or several municipalities as well as industries. It may concern very small works or very large ones. Particular emphasis is placed on joint projects which will serve a number of municipalities, whether these be for water supply or sewage disposal.

2. Projects undertaken by the Commission are, in general, confined to works for the supply, purification, and delivery of water through feeder mains to the contracting party's distribution system, or to trunk sewers, treatment works and sewer outfalls. It is only in the case of small communities that the Commission undertakes the construction of the local water distribution mains or the sewage collection system. In those instances there is a definite advantage to having all the work done under the one contract and under one management.

3. When the agreement has been approved by both parties, the Commission goes forward on the necessary plans and specifications. The policy of the Commission has been to appoint consulting engineers to do the design work and also to do field supervision during construction. Thus, the consulting engineer is an employee of the Commission rather than the municipality. He engages the resident engineers and field staff to supervise construction. The Commission on its own maintains a construction branch, to deal with this work and to ensure that the project is carried out to its satisfaction.

4. All contracts for these projects are awarded by the Commission, and the complete program is under the direct responsibility of the Commission. Payments are made to the contractor as work progresses, and also to the consulting engineers. In this way, no payments are made by the contracting municipality until the works are in operation.

5. The agreement between a municipality and the Commission is based on the latter's assuming responsibility for the

operation and maintenance of the works during the lifetime of the debt. When the project is constructed, the responsibility of this passes from the Construction Division of the Commission to the Operating Division. The personnel for these operations are engaged by any paid for by the Commission. Where there are small works, and these do not require the services of a full-time staff, arrangements may be made to employ on a part-time basis some of the local employees of the municipality or others, as the case may be.

6. The agreement between the municipality and the Commission contains a clause whereby at the termination of the debt, the works may be returned to the municipality at the request of either party. Extensions or enlargements of the works may be made by the Commission at the request of the municipality, and in this way the debt retirement period may be extended for a longer period. Each of these extensions involves a new agreement between the Commission and the municipality, and the Commission would not have the right to extend the original works under the terms of the first agreement.

7. An important part of this entire program is the means for co-operation between the Commission and the municipalities served. Each municipality is asked to appoint a local advisory committee, to work with the Commission and to deal with all aspects of the program. In this way there is local direction for such matters as appointment of employees, wages paid, and many other features of administration. This tends to relate the activity to local needs rather than having one set of standards or requirements for the entire Province.

8. The Commission offers to each municipality extensive services in the operation of the works. There is the closest co-ordination of all technical matters in which the advice of the local engineering staff is combined with the specialized training of the Commission personnel. In small municipalities where new works are being installed and where there has been little local experience on such matters, the Commission advises on all aspects of the administration, including rate structures, book-keeping, records, etc. In this way, full use is accorded each municipality of the Commission's laboratory facilities and its technical staff without cost to that community.

Financing Commission Projects

The financial arrangements for the projects constructed and operated by the Commission are an important part of the over-all program. Stringent money conditions, including the difficulty of raising loans, and high interest rates have added to the burdens of municipalities in financing undertakings on their own. Under the plan offered by the Commission, the municipality does not issue or sell any debentures or bonds. Money is advanced by the Commission, and the credit of the Province is pledged for this. The debt is paid back over a long period, 30 years in most instances, but varied according to the wishes of the municipality. The interest rate is the actual cost of money borrowed by the Province. This rate is normally lower than it is possible for the municipality to obtain on the open market. The indebtedness of the Commission can be met by the sale of its own bonds, which are guaranteed by the Province, or it can borrow directly, as it has to date, from the Provincial Treasurer, thereby gaining the advantage of borrowings on a large scale.

A number of advantages are to be found in this method of financing in addition to the more favourable interest rate. One is the flexibility of the agreement. The municipality makes no payment to the Commission until the work is put into operation. The debenture period may be made to suit local needs. Principal payments may be deferred at the outset and up to a period of five years after the work is completed. The interest rate will vary each year, and as the recent high interest rate is lowered, the municipality obtains this advantage of further saving.

In Ontario, all financial obligations to be incurred by municipalities come under the supervision of the Ontario Municipal Board. The Board thus determines whether the obligation is within the ability of the municipality to carry. This same requirement applies whether the municipality is doing the work on its own, or whether the work is under The Ontario Water Resources Commission. In the latter instance, the Commission deals directly with the Board for the municipality.

Where a number of municipalities or other parties are concerned with a single project, the agreement provides for alloca-

tion to each of these that part of the capital debt for which they will be responsible to the Commission. The cost of the water delivered or the sewage treated is based on this and the actual cost of operation. The Commission has undertaken and is continuing to undertake projects in which a number of municipalities are provided with joint service, including feeder water mains and trunk sewers and treatment facilities.

The basis of all financial agreements with municipalities is that they shall pay to the Commission the actual cost of the debt and service rendered. The latter does not include the supervisory services of the Commission, but only those operators actually engaged on the project. No money grants are involved in these programs. The contracting municipality will pay quarterly to the Commission the estimated amount of capital and operating charges as well as a reserve fund for contingencies, repairs and replacements. At the end of the year an adjustment is made with the actual costs for that period. These financial procedures relieve the municipality of all details involved in borrowing money for capital works.

Sanitary Supervision over Water and Sewage Works

The other part of the Commission's program, involving sanitary supervision over water and sewage plants, is similar to that which is normally carried out under a Provincial health department. All plans for water and sewage works or extensions to existing works require the approval of the Commission before construction is undertaken. In this way, the Commission is given wide powers to deal with the water resources of the Province and has the right to regulate water use.

Great emphasis is placed on the control of stream pollution. If water resources are to be made available for the maximum use and public benefit, pollution control must be exercised rigidly. The Commission under the legislation is empowered to deal with the protection of all water supplies. Heavy penalties are provided for infringement of this. A departure from the usual public health provision against pollution is that under the Commission's program this is not to be confined to something which may only affect public health, but rather is it widened to include

anything which may impair the quality of the receiving watercourse. A good deal of the activity of the Commission since its inception has been devoted to sewage and waste disposal and to the abatement of stream pollution.

Organization of the Commission

The Commission's program has been organized to give effect to these various activities. The Commission, at present consisting of six members, decides on all matters of policy. The administration of these policies comes under a General Manager, acting through six divisions or branches. These consist of Administration, Laboratories & Research, Construction, Plant Operations, Sanitary Engineering, and Water Resources. The staff has grown at a rapid rate and at present is near 200, along with nearly 100 plant operating staff. A new laboratory has been recently put into operation, to serve the needs of the Commission and to give service to all municipalities operating water and sewage works. Research programs will be emphasized in this laboratory, and there will be full co-operation with industry and with municipalities.

Progress under the Commission

The program of the Commission is as yet in early stages. The revised act of the Legislature came into effect only in April, 1957. Since that time it is gratifying to note the number of projects which have been undertaken. To date, agreements have been made with municipalities for 130 projects for works involving an estimated expenditure of over $51,000,000. These include 66 water projects and 63 sewage works. Over 60 of these are already in operation, and others are in various stages of development. In many other instances agreements are pending, and preliminary engineering work is being done. These include both small and large works. Sources of water supply, both surface and underground, will be developed wherever they are considered most advantageous. Sewage treatment will be provided to meet the local needs, and trunk sewers will be constructed to treatment plant sites or to outlets. Municipal boundaries are not to be regarded as the basis for either the supply of water or the

treatment of sewage, but rather these are considered to be area problems, so that regardless of the municipality in which the area is situated, it may be combined with the adjacent area to advantage and to economy for all concerned.

The boundary waters between Ontario and the United States offer a challenge in the effective control of pollution. These waters with unsurpassed international value must possess high quality to serve their many functions. The International Joint Commission has made surveys and has maintained close contact. Enforcement of quality standards set by the International Joint Commission has been carried out on the Canadian side by the Ontario Water Resources Commission. This is a co-operative effort, designed to reach the desired objective of good stream sanitation and protection of water resources.

Good progress is being made on pollution abatement in the boundary waters. The OWRC is participating in the building of municipal plants and is co-operating closely with industry in their waste treatment problems. Joint efforts can be most effective, and in the boundary waters there is every expectation that the desired results will be a reality in the near future.

Summary

A review of the program of the Ontario Water Resources Commission at this time emphasizes the significance of the original objective to facilitate the development of water supplies and the treatment of sewage disposal facilities for all municipalities, where they be inland or on large bodies of water. The Province has adopted a program for the development and conservation of water resources and for pollution abatement with full protection of all watercourses in the Province. This pertains to municipalities and industries. A great deal of effort is being devoted to surveys of all water sources, and for determination of discharges to watercourses. The new laboratory, now in full operation, is making over 15,000 analyses per month of water, sewage, and industrial wastes, all utilized to assist in the program of the Commission. Special efforts are being directed to the control of drainage outfalls in small municipalities as well as large ones. In this way, it is hoped to be able to clear all

streams of pollution. This is a further step in a program aimed at close co-operation between the Province and the municipalities. The results obtained to date have been most gratifying, in spite of the heavy expenditures required for these works. It is not possible to predict with accuracy the length of time needed to deal with these major water and sewage programs, but the work is proceeding at a rapid pace. There has been splendid co-operation received from municipalities and from industry. The Commission can look forward with optimism.

Modern methods of water purification are employed, and the degree of treatment of sewage and industrial waste is aimed at the protection required for each watercourse. Naturally this will vary according to local conditions. The trend, however, is definitely towards more complete treatment and for raising the standard of stream sanitation throughout the Province. As the treatment works continue to come into operation, rigid control is being exercised by the Commission, to prevent the discharge of untreated or inadequately treated wastes or further pollution of any stream. In this objective, it is felt that the population growth can go forward, and industry can expand, while at the same time streams can be utilized fully for disposal of these effluents without undue impairment of their quality or their usefulness. Co-operation of all concerned, which is the basis of this program, cannot fail to achieve the desired results.

RADIOACTIVE FALLOUT AND DRINKING WATER

BY ERNEST A. SNOW*

[*Presented Sept. 21, 1960.*]

1. The Problem

The introduction of nuclear weapons in World War II and the weapons testing program since 1945 have brought a new problem to the water works engineer.

The occurrence of radioactive fallout focused public attention on man's exposure to artificial radiation.

Considerable information has been accumulated in the past twenty years on the amount of exposure to which man has been subjected.

The collection of physical data is difficult and expensive but the most difficult problem is the interpretation of the biological effects of radiation; more on this later.

The use of nuclear energy may be divided into several categories as follows:

1. Nuclear weapons used in actual warfare.
2. Nuclear weapons testing.
3. Use of nuclear energy to produce electric power.
4. Use of radioactive isotopes in industry, research and medicine.

Since all of the above categories produce radioactive wastes the problem of the disposal of these wastes is one of the most urgent for the sanitary engineer. Some of these wastes eventually become water borne and may become a hazard to drinking waters. Radioactive wastes differ from ordinary industrial wastes in many respects.

They cannot be neutralized but must be actually removed and contained. When present in streams they do not show dramatic visual effects as may be the case with certain industrial wastes but nevertheless they may have serious effects upon

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public health. Through biological processes they may enter man's food chain, e.g. Sr^{90} in milk. Water treatment plants generally do not have quality controls for radioactive contaminants. Therefore, some type of control should be planned, even if only at the present time at the state and federal level.

Fallout and Fallout Patterns.

The gradual accumulation of debris from bomb tests on the earth's surface has been called fallout. There are three classes of fallout; *local*, deposited closeby in the first 24 hours after the detonation of a bomb, *intermediate*, within 30-60 days (also called tropospheric) and *delayed* fallout, over many years, also called stratospheric. (1)

Local fallout is rapid but the pattern depends chiefly on winds. With low velocity winds, a small area will become highly radioactive. A heavy wind spreads the area and dilutes the radioactivity.

Intermediate fallout results from bomb material that contaminates the troposphere and then settles out gradually over a period of 1-2 months. The amount of fallout of this type depends greatly upon rainfall and winds. A heavy rainfall may scavenge the material and deposit it in a relatively small area.

Delayed fallout is an important problem from our point of view. It is due substantially to fission products from air bursts. This type of fallout is widespread and global. The degree of fallout is a function of the bomb size and point of detonation.

There are several patterns which delayed fallout takes. First on a global scale there is a sharp peak in amount of fallout in the temperate latitudes of the Northern Hemisphere, a second maximum in the corresponding latitudes of the Southern Hemisphere and a minimum at the equator. Both soil analyses and rainfall analyses show this type of curve. The study of Sr^{90} and shorter lived fission products shows that most of the delayed fallout in the temperate latitudes is from the stratosphere.

Another pattern of fallout is the seasonal variation in Sr^{90} removal from the stratosphere with a peak value in spring or late winter.

Fallout of Sr^{90} is also proportional to the amount of annual rainfall.

Another fallout pattern characteristic is the spread from west to east according to the prevailing winds. In the U. S. fallout values have also been consistently higher in the northern tier of states as compared to the southern states.

Local concentrations also occur. One example is the concentration in the Albany-Troy region of New York 2000 miles from the Nevada test site. A rapidly moving nuclear cloud at 40,000 feet was scavenged by an intense thunderstorm to give this effect.

Another example is the collection of a "hot" snow after a snowstorm in Amherst on April 8, 1957. This sample had an initial count of 2000 per minute. The half-life of this material was about 2 weeks.

The Effects of Radioactivity on Man

If a person receives a massive dose of radioactivity various symptoms of acute radiation sickness soon show up. Some of the early symptoms are: nausea, vomiting, loss of appetite, fever and internal bleeding. Further clinical signs are loss of hair, lower white blood cell counts, dehydration, malnutrition and subsequent bacterial invasion.

If an individual receives frequent smaller doses of radiation delayed effects may result. These changes may include premature aging, abnormal growth, genetic effects and skin changes.

The following table shows approximate whole body dosages that result in radiation injury:

Dose in roentgens	*Probable effect*
0-50	None obvious; possible minor blood changes
80-120	10% of those exposed will have nausea and vomiting
130-170	25% of those exposed same as above for 1 day
180-220	50% of those exposed same as above for 1 day
270-330	All V & N first day; 20% deaths; 3 mo. to convalesce
400-500	All V & N; 50% deaths in 1 mo.; 6 mo. to recover
550-750	All V & N within 4 hr.; near 100% deaths
1000	Radiation sickness in 1-2 hr.; 100% deaths
5000	Incapacitated at once; 100% fatal within 1 week

When radioactive materials enter the body they may migrate to and concentrate in certain organs. For example iodine concentrates in the thyroid. Strontium collects in the bones along with calcium. The radiations from Sr^{90} can damage the bone marrow cells which normally produce blood cells. If the marrow cells are damaged they may lead to an overproduction of white blood cells (which condition is called leukemia). Many radiation victims die from leukemia.

There are two effects of radiation on man which complicate things and make it extremely difficult to set up rational and definite maximum permissible dosages. The effects we have noted above are the somatic effects on the ordinary body cells.

The genetic effects of radiation are even more elusive. They are the effects on the genes, gametes and gonial cells. Gene mutations can be caused by radiation, these mutations usually have harmful effects on later generations.

Most of our knowledge about genetic effects comes from experiments with animals. Extrapolating these results to man is difficult. We need to devise some method of assessing the genetic health of human populations so we can predict what effects radiation damage may have on future generations. It is not even known whether or not there is a threshold dosage below which the effect on man is negligible or whether effects of exposure are linear. Until we know some of these answers we should proceed with caution and try to keep radiation exposures to a minimum consistent with progress.

Maximum Permissible Concentrations

Since 1929 the National Committee on Radiation Protection and Measurements has been concerned with problems of radiation protection. This was before the development of nuclear weapons and was concerned with x-rays and natural radioactivity (esp. Ra). With the development of man-made radio isotopes the work of the committee was greatly expanded and standards were recommended to prescribe the maximum permissible radiation dosages for humans which should not be exceeded without good reason. (2)

In 1957 the A.E.C. adopted lower levels of permissible ex-

posure, basing its recommendations on those of the National Committee on Radiation Protection. (These are again being currently lowered furthered.) The latter observed "that the changes in accumulated permissible dosage are not the results of positive evidence of damage due to the use of earlier dose levels but are based on the desire to bring the M.P.D. into accord with the trends of scientific opinion."

2. Concentration of Radioactivity by Natural Agents

Even before the advent of the atomic bomb man was subjected to a certain amount of radioactivity. Naturally occurring radioisotopes are dispersed throughout the world in soil, water and air. The table below shows some of these radiation sources. In addition to the radioactive elements outer space has been sending us the very penetrating cosmic rays. (3)

Cosmic rays—70% of background at sea level

In rocks and soil U series 6 ppm by wt.

Th series 12 ppm by wt. $Ra = 2 \times 10^{-6}$ ppm

K^{40}, Rb^{86}, Sm^{152}, Lu^{176}, Re^{187}

Radon in air 10^{-10} μc/cc

Fresh water 10^{-9}–10^{-10} μc/cc average, but varies

Sea water 3.3×10^{-7} μc/cc due mostly to K^{40}

Normal background radioactivity is that amount present due to the above components before the use of man-made radioactive isotopes. Certain chemical and physical factors lead to reconcentration of radioactivity. Sedimentation is the settling of heavier particles in water. Temperature may lead to evaporation or crystallization (and often with pressure as a factor). Freezing of liquids may concentrate by extruding impurities. Chemical factors may include adsorption, flocculation, ion exchange, precipitation, etc.

Biological concentration of radioactive isotopes is of great importance since it has been shown that even small organisms can concentrate certain isotopes by very large factors. In this way they may enter a food chain such as one which may end up in fish or shellfish used as food by man.

Radioactive Isotopes in Water

An atom bomb explosion produces a large number of fission products. The Uranium atom does not split in half as might be expected but the distribution of species in asymmetric. Among the products are the following: Sr, Y, Zr, Nb, Mo, Ru, Rh, Te, I, Xe, Cs, Ba, La, Ce, Pr, Nd and Pm. (4)

The half lives of these are all different, so that at any given time after fission there are different ratios of each. After one year the main active components are: Sr^{90}–Y^{91}, Zr^{95}–Nb^{95}, Ru^{106}–Rh^{106}, Cs^{137}, Ba^{137}, Ce^{144}–Pr^{144} (over 26% of the latter pair) and Pm^{147}.

In spite of these ratios, the most important from a public health standpoint are Sr^{90} and Cs^{137} which both have long half lives. (25 yr. and 30 years resp.)

Strontium is important because it is a bone-seeker, similar to calcium in biological uptake, also since it enters the food chain, from grass to cow to milk to man.

Cesium is also a hazard since it can be concentrated by algae and enter food chains, also because it is very soluble and difficult to remove from water.

Recently it has been shown that both Chlorella and Euglena can concentrate Cs^{137}, especially in heavy blooms. We would expect Cs^{137} in nature to be cycled out of solution and carried to the bottom by algal blooms. The hot detritus on the bottom would then affect bottom dwelling organisms. (5)

The Fate of Fallout in Water

Just what is the final result of fallout in waters. This depends partly on the solubility of the material and the size of particles.

Very soluble materials such as Cs will tend to stay in solution and travel with the water or be concentrated by algae.

An example of a soluble element is potassium and the amount in various water supplies has been determined to vary from less than 1×10^{-9} to 24×10^{-9} μc/cc. (*i.e.* natural K^{40}).

Most insoluble materials will end up by dropping into the bottom mud.

For example, in one reservoir examined the water varied from 48 μμc/1. at the surface to 20 μμc/1. at 60 feet; the mud contained 98 μμc/gm or about 2000 times as much as at the surface.

Schmutzdecke and sand at different levels from a slow sand filter showed the following:

Schmutzdecke—1770 μμc/gm
Sand, 2″ depth—1020
Sand, 10″ depth—427

This would indicate a concentration factor of about 2 million compared with the surface water. Actually we do not know how long it took to build up this concentration or whether the surface water contained much larger amounts of fallout at times of heavy rainfall (which is very likely). This concentration of fallout in slow sand filters is of common occurrence and has also been shown to occur in slimes on pipes, etc. In fact it has been shown that much of the radioactivity on algae is due to sorption on the slimy excretions on the outer cell walls. It was also shown recently that ferric iron aided the adsorption of Ru on sand particles.

In an effort to determine what isotopes are present in schmutzdecke, a sample was ashed, concentrated with nitric acid and separated into groups chemically:

	cpm (beta-gamma activity)	*May show:*
Silver chloride group	19.8	Xe, Ru, I
Acid sulfide group	15.2	Nb, Zn, Mo
Hydroxide group	240.0	Ce-Pr
Basic sulfide group	27.8	Co^{60}
Phosphate group	23.5	Sr
Alkali group	16.7	Cs

The above result would indicate that the fallout material was probably a year old or even older, due to the relatively large amount of activity in the hydroxide group present.

3. Methods of Decontamination

a. Conventional water treatment

b. Modified water treatment

c. Emergency water treatment

a. Conventional processes include coagulation, settling, filtration, disinfection, aeration, softening and occasionally iron and manganese removal. Coagulation removes in excess of 90% of most cations with a valence of 3 or more, also $P^{32}O_4$, for I^{131} as iodide when silver nitrate is used and for Pu, but Cs and Sr are not removed to any substantial degree. Filtration. Clean filters remove only the isotopes associated with suspended solids. Slow sand filters with a schmutzdecke remove a larger percentage of the nuclides. Lime soda ash softening removes most fallout except cesium (but including Sr). High removal of the latter may be obtained with excess lime. Ion exchange resins either as separate cation and anion columns or as mixed beds remove large percentages. This method can prove expensive, however, due to short runs with high dissolved solids.

b. Among the modifications which may be used for radionuclide removal are phosphate coagulation, iron filings or metal dusts, clay materials, electrodialysis and distillation. These methods all have their drawbacks, however. The following table gives a rough picture of the efficiency of the various processes:

Decontamination methods:—Plain settling—60-90% removal; Coagulation—5-75% removal; Filtration—85-90% removal (after coagulation); Ion exchange—99-99.9% removal; Distillation—99-99.99% removal; Metal dusts—90% with iron except for I^{131} and Cs^{137}.

c. For emergency treatment several types are suitable for use on a small scale. Ion exchange and distillation give good results. A multibed unit using steel wool, clay, activated charcoal and mixed bed resin was developed and tested by Lauderdale and Evans. Conventional methods may be totally inadequate in case of heavy fallout. As a rule ground waters are safer than surface waters.

Instruments and Methods

Instruments for the measurement of radioactivity vary from simple film badges and pocket dosimeters to expensive gamma spectrometers.

For waterworks monitoring I will mention only the bare essentials.

First some type of portable beta gamma survey meter can be used for field work and detecting spillage or contamination of the laboratory. For low-level monitoring the most useful instrument is the internal proportional counter. The reason for this is that the efficiency is higher than with an end-window G.M. counter; also by changing the voltage of operation either alpha or beta-gamma activity can be counted.

Another instrument that is valuable is the gamma spectrometer. This can be used for detecting individual gamma emitting isotopes.

Many other types of apparatus are available and improvements are being made each year but the three mentioned are basic. There are two methods used in monitoring work. Gross measurements of over-all activity of a sample or separation and identification of individual isotopes.

Gross beta-gamma activity can be measured by concentrating the sample by evaporation, and its transference to a planchet for measurement. The instrument may be calibrated with known activities of Sr^{90} or $T1^{204}$. All samples must be weighed in order to be able to obtain the thickness in mg/cm^2 since the calibration curve makes allowance for self absorption, allowing the efficiency to be read from the curve.

$$\text{Efficiency} = \frac{\text{c.p.m.}}{\mu\mu\text{c (activity added)}}$$

The laboratory work involved in the separation and identification of isotopes is much more complicated and time consuming than gross measurements. However, it may be necessary whenever samples exceed the M.P.C. and something needs to be done about it.

Many schemes have been worked out for chemical separa-

tions using carriers. The work has been shortened by using the centrifuge in place of filtrations. Final measurements of radioactivity are made by using the counters or spectrometer mentioned above.

Detailed information on these methods can be obtained from the Manual on Radionuclide Analysis of Environmental Samples put out by the Taft Sanitary Engineering Center at Cincinnati as Technical Report R59-6.

The Public Health Service offers short courses on various phases of water pollution and analysis including radioactivity. These courses are a great help in training personnel from the various states and cities.

Conclusions

It is my personal opinion that the future use of nuclear weapons in warfare would give rise to very serious and difficult problems for the water-works operator. The effects of widespread nuclear warfare would be cataclysmic and homicidal.

Radioactivity Results in μμc/1. (Beta-Gamma Activity)
Deerfield River in Massachusetts — 1958-1960

Date	Sta. A	Sta. B	Sta. C
4/7/58	22.1	31.7	26.0
4/9/58	30.2	17.9	39.4
7/16/58	53.0	16.9	42.0
2/18/59	37.4	36.8	30.8
6/11/59	24.0	23.0	22.0
12/17/59	33.6	4.78	14.7
5/27/60	9.1	10.9	12.4
6/9/60	3.9	13.0	14.2
7/25/60	9.7	6.01	14.5

If the above figures can be assumed to be representatitve, we see that in the last three years there has been a marked drop in radioactivity. This is undoubtedly due to the cessation of weapons testing on a large scale.

Since the cessation of nuclear weapons testing the radioactivity in water supplies has been falling to a lower and safer level. However, with the increasing use of nuclear energy for the production of electricity and the increased use of isotopes in industry, the monitoring of our water supplies should be continued and expanded. Monitoring of potential water supplies

(esp. rivers) should also be carried out, to safeguard against pollution from atomic reactors or industry where indicated.

Radioactivity should be considered as a form of pollution, more insidious than other forms and more difficult to measure. It follows that radiological health personnel and those waterworks personnel involved must be carefully trained for their duties.

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WATER-BORNE TYPHOID EPIDEMIC AT KEENE, NEW HAMPSHIRE

BY WILLIAM A. HEALY* AND RICHARD P. GROSSMAN†

[*Read September 21, 1960.*]

As an introduction to this discussion of the Keene typhoid epidemic, which occurred in the later part of 1959, a brief description of the character of the watershed areas and the quality of supply will be of interest. The City of Keene was one of the first New Hampshire communities to undertake the construction of a public water supply system. Records on the subject indicate that in 1867, the sum of $82,000 was voted to purchase lands surrounding Goose Pond (42 acres), later called Sylvan Lake, and to install the necessary supply main and distribution lines in the central part of the City.

Goose Pond is about three miles north of the City, has a drainage area of 1.84 square miles and a safe yield of 1.08 m.g.d. The watershed is largely wooded, completely uninhabited and the shoreline is entirely controlled by the municipality. No recreational use is permitted and the pond is visited regularly for observation as to compliance with the sanitary restrictions in force.

Analytical records for this source of supply demonstrate that the bacterial quality of the raw water is excellent and falls well within the recommended M.P.N. limit of 50 coliforms per 100 ml. for acceptance as a drinking water supply after chlorination. Originally flow to the City was by means of gravity but Goose Pond water, which is now on a standby emergency basis, is delivered to the system by means of a 1,000 g.p.m. centrifugal pump, manually operated, located in a booster station approximately one mile downstream of Goose Pond. Simple chlorination is provided by a vacuum type chlorinator which operates whenever the pump starts.

Due to continued population and industrial growth, the

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City in 1886 turned to Woodward Pond (Echo Lake) in the neighboring towns of Roxbury and Nelson for additional supply. This body of water (104 acres) is located about five and one-half miles east of the City proper, and the natural lake level was increased ten feet by the construction of a dam. An intake structure, Quarry Dam, was developed about three miles below on the outlet stream, Roaring Brook, and water was delivered by gravity to the one-million-gallon Octagon Reservoir on Beech Hill through three miles of 8-in. pipe. Later, in 1902, Stone Dam was constructed, one and one-quarter miles below Quarry Dam, impounding two million gallons, and a 12-in. supply main was laid through Marlboro Street into South Keene, connecting to the southern end of the distribution system (see Figure 1).

These facilities constituted the source of supply for several years and it might be well to note that as in the case of the Sylvan Lake development, the City did acquire considerable amounts of land in the watershed area for control and protective purposes. Despite such measures the Woodward Pond supply was essentially an untreated stream system and as such, more or less variable as to bacterial quality depending upon run-off conditions. Accordingly, it is not surprising that an epidemic of gastro-enteritis, with some 500 to 1,000 cases, involving the public water supply as the transmission agent, occurred in October, 1923. Following this incident, slow sand filters were installed at Beech Hill and Stone Dam. A 1.5 m.g. reservoir was also included in the Beech Hill project. The Beech Hill plant capacity was rated at 750,000 g.p.d., at 5 m.g.d. per acre, and is operated at 0.9 m.g.d. At Stone Dam 1.5 m.g.d. capacity, at 5 m.g.d. per acre, was provided, which later was increased to 3.0 m.g.d. by the construction of two additional filters in 1952. These filters are operated at 1.1 m.g.d. due to limitations in transmission capacity. In 1931 Babbidge Reservoir with a capacity of 160,000,000 gallons was developed about one-quarter of a mile above Stone Dam.

Except for certain improvements in intake pipe capacities and the development of a gravel-walled well (the bacteriological record of which is excellent) in West Keene, the supply for the City remained in this stage up to the time of the typhoid

epidemic in October-November, 1959. In passing it might be of interest to observe that the watershed area of the Roaring Brook source amounts to 4.9 square miles and the safe yield is 2.55 m.g.d. There are only a few dwellings on the watershed, a limited number of roads, most of which are little used, and some of which are impassable. In essence then we have a remote, lightly inhabited watershed, mostly wooded and one obviously capable of producing a supply safe for drinking with a minimum in the way of treatment. A review of the analytical records on raw water samples submitted to the state and local health department laboratories from the Roaring Brook supply, during the period since July, 1956, to the time immediately prior to the typhoid outbreak, discloses that the quality conforms to the U. S. Public Health Service "Manual of Recommended Water-Sanitation Practice" (1946) for surface water supplies to be subjected to simple chlorination, which requires that the average Most Probable Number of coliform organisms in any one month shall not exceed 50 per 100 ml. A composite of these results appears in Table 1 and a similar tabulation for distribution-system quality is presented in Table 2. It is of interest to note from the tables that raw water quality meets the recommended practice throughout the period of tabulation except for the month of October, 1959, at which time the epidemic started.

The U. S. Public Health Service Drinking Water Standards require that:

(1) Of all the standard ten milliliter portions examined per month, in accordance with the specified procedure, not more than ten percent shall show the presence of organisms of the coliform group.

(2) Occasionally three or more of the five equal ten milliliter portions, constituting a single standard sample, may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than:

   (a) Five percent of the standard samples when twenty or more samples have been examined per month.

   (b) One standard sample when less than twenty samples have been examined per month.

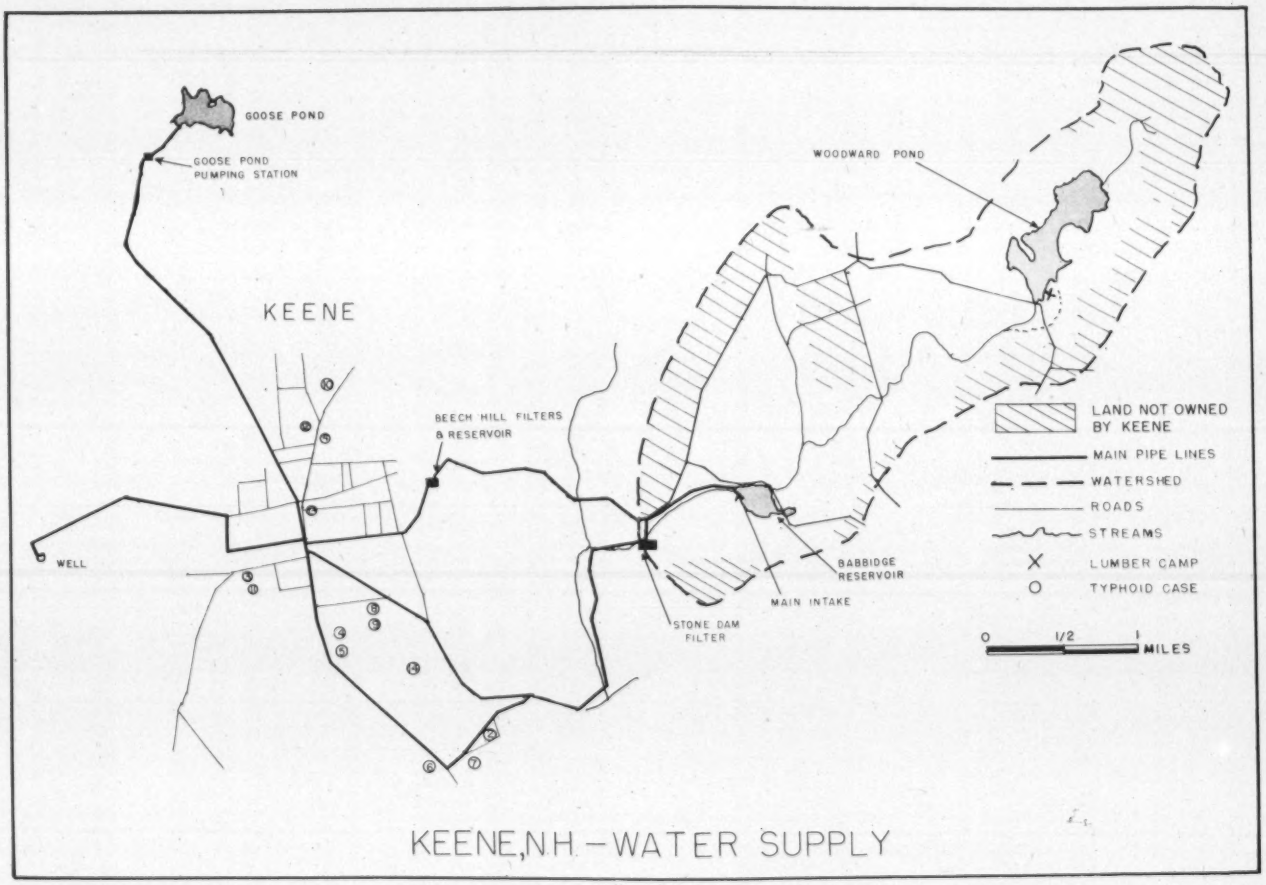
GOOSE POND
GOOSE POND PUMPING STATION
KEENE
WOODWARD POND
BEECH HILL FILTERS & RESERVOIR
WELL
BABBIDGE RESERVOIR
MAIN INTAKE
STONE DAM FILTER
LAND NOT OWNED BY KEENE
MAIN PIPE LINES
WATERSHED
ROADS
STREAMS
LUMBER CAMP
TYPHOID CASE
0 1/2 1 MILES
KEENE, N.H. – WATER SUPPLY

FIG. 1

TABLE 1—BACTERIOLOGICAL RESULTS—KEENE, N. H., WATER SUPPLY RAW WATER
July, 1956, to July, 1960

Date	No. of samples	No. positive samples	MPN/100 ml. Range	MPN/100 ml. Average	Date	No. of samples	No. positive samples	MPN/100 ml. Range	MPN/100 ml. Average
1956					*1958*				
July	16	8	2.2-15	5.0	July	11	8	2.-2-5.0	2.9
Aug.	16	8	2.2-38	9.1	Aug.	15	2	2.2	2.2
Sept.	11	9	2.2-15	6.0	Sept.	13	3	5.0-15	9.6
Oct.	13	1	5.0	5.0	Oct.	15	6	2.2-240	82.4
Nov.	12	0	—	—	Nov.	10	1	2.2	2.2
Dec.	13	2	8.8-15	11.9	Dec.	16	1	2.2	2.2
1957					*1959*				
Jan.	12	3	2.2	2.2	Jan.	13	0	—	—
Feb.	9	0	—	—	Feb.	7	0	—	—
Mar.	12	0	—	—	Mar.	13	0	—	—
Apr.	12	0	—	—	Apr.	14	2	2.2-5.0	3.6
May	16	1	2.2	2.2	May	11	0	—	—
June	12	5	2.2-38	9.9	June	13	4	2.2-8.8	5.2
July	16	10	2.2->240	?	July	13	6	2.2-240	44.9
Aug.	10	3	2.2-5.0	3.1	Aug.	14	8	2.2-15	4.5
Sept.	14	6	2.2-15	4.8	Sept.	11	8	2.2-8.8	4.2
Oct.	15	3	2.2-8.8	5.3	Oct.	12	10	2.2-240	73.5
Nov.	11	0	—	—	Nov.	11	9	2.2-15	3.9
Dec.	12	5	2.2-240	52.8	Dec.	12	4	2.2-240	61.6
1958					*1960*				
Jan.	12	3	2.2-8.8	6.6	Jan.	14	0	—	—
Feb.	11	0	—	—	Feb.	12	0	—	—
Mar.	15	0	—	—	Mar.	12	0	—	—
Apr.	11	0	—	—	Apr.	13	0	—	—
May	12	1	2.2	2.2	May	12	0	—	—
June	13	3	—	16.3	June	15	0	—	—

An examination of Table 2 reveals that distribution-system water quality failed to meet these standards on some occasions and, while generally good quality is indicated during the period of record, it is of significance that October, 1959, is included as one of the months of failure to satisfy the standards.

Experience with slow sand filters suggests that the percent efficiency in the removal of bacteria which can be expected is in the range of 98 to 99 percent. However, at Keene the rate of operation at the Beech Hill filters has been appreciably above the conventional loading of 2.5 m.g.d. per acre, and this would tend to decrease the efficiency of removal. Much more important, however, is the problem of greatly lowered efficiency immediately following the cleaning of filters and this inherent characteristic is readily discernible from an examination of laboratory data collected during the typhoid incident. Also a study of the routine analyses of distribution system samples will show a very close correlation with water plant records as to times of filter sand cleaning. This deficiency caused the State Department of Health and the City's Consultant, Camp, Dresser and McKee, to recommend several years ago the regular use of chlorination for disinfection purposes.

However, in view of the generally good conditions prevailing in the watershed, the absence of water-borne illnesses, confidence in the existing filtration facilities and in particular, a strong aversion to a chlorinated supply, the City government rejected these recommendations.

October, 1959, was a month of heavy rainfall with especially heavy precipitation being experienced on the dates of October 24 and 25. As will be noted from Table 3, the rainfall for October 25th alone was 1.3 times the monthly average and this coupled with the previous day's rainfall resulted in a situation of extremely high runoff in the watershed area. That this condition obtained is readily evident when we examine the laboratory results for this portion of the month (Table 4). Clearly, any pollutional material present in the upper reaches of the drainage basin would quickly be transported down into the system and later investigation established that this is precisely what happened. On Friday, October 23, just preceding

TABLE 2—BACTERIOLOGICAL RESULTS—KEENE, NEW HAMPSHIRE, WATER SUPPLY DISTRIBUTION SYSTEM

July, 1956, to July, 1960

Date	No. of samples	No. positive samples	MPN/100 ml. range	% 10-ml. tubes positive	Date	No. of samples	No. positive samples	MPN/100 ml. range	% 10-ml. tubes positive
1956					*1958*				
July	42	7	2.2-8.0	4.8	July	42	8	2.2	3.8
Aug.	44	5	2.2-8.8	3.7	Aug.	42	0	—	0
Sept.	46	7	2.2-8.8	4.8	Sept.	42	2	2.2	1.0
Oct.	42	2	5.0	1.9	Oct.	46	2	2.2-15	2.3
Nov.	40	0	—	0	Nov.	28	2	2.2	1.4
Dec.	36	3	2.2	1.7	Dec.	46	1	2.2	0.4
1957					*1959*				
Jan.	41	3	2.2-240	3.5	Jan.	38	1	2.2	0.5
Feb.	36	0	—	0	Feb.	26	0	—	0
Mar.	38	0	—	0	Mar.	45	0	—	0
Apr.	40	1	38	2.5	Apr.	43	0	—	0
May	45	1	2.2	0.5	May	38	0	—	0
June	34	7	2.2-15	6.5	June	39	1	38	2.6
July	48	9	2.2	3.7	July	42	10	2.2-5.0	5.2
Aug.	38	4	2.2-7.6	3.2	Aug.	42	13	2.2-240	14.8
Sept.	40	7	2.2-21	6.0	Sept.	40	16	2.2-5.0	9.0
Oct.	48	1	2.2	0.4	Oct.	42	12	2.2-240	11.9
Nov.	36	0	—	0	Nov.	36	10	2.2-8.8	6.3
Dec.	38	6	2.2	3.2	Dec.	46	5	2.2-8.8	3.0
1958					*1960*				
Jan.	38	2	2.2	1.1	Jan.	42	0	—	0
Feb.	36	0	—	0	Feb.	40	0	—	0
Mar.	44	1	5.0	0.9	Mar.	46	0	—	0
Apr.	35	2	2.2-5.0	1.7	Apr.	41	1	5.0	1.0
May	42	2	2.2-15	2.4	May	42	1	5.0	1.0
June	42	1	2.2	0.5	June	46	2	2.2-38	2.6

TABLE 3—PRECIPITATION FOR THE MONTH OF OCTOBER, 1959, AT KEENE, NEW HAMPSHIRE

Date	Rainfall in inches
October 1	.08
2	.52
6	.52
7	.53
8	.45
9	.56
10	.13
12	.20
14	.01
18	.16
19	.07
21	.02
23	.28
24	.73
25	3.56
27	.02
31	trace
Total	7.84

Mean rainfall for month of October—2.7 inches

TABLE 4—BACTERIOLOGICAL RESULTS—KEENE, N. H., WATER SUPPLY—RAW AND DISTRIBUTION SYSTEM

October 26 to November 12, 1959

Date	MPN/100 ml. in raw water	MPN/100 ml. in distribution system	
October 26	240		
27		38	5.0
28	240	38	15
29		2.2	
30	38		
November 2	15	2.2	8.8
3		2.2	2.2
5		2.2	2.2
6	5.0	< 2.2	< 2.2
10		< 2.2	2.2
12	2.2	< 2.2	< 2.2

the heavy rainfall of the 24th, one of the four slow sand filter units at Stone Dam was cleaned and placed in service shortly thereafter, in accordance with regular routine. Referring again to Table 4, the records of distribution-system sample collections for the dates of October 26, and immediately following, showed evidence of substantial numbers of coliform organisms. Also raw water collections from Babbidge Dam for the same period, indicated coliform counts appreciably higher than normal, however, apparently no great significance was attached to these findings at the time. As a matter of fact, it will be recalled that elevated counts in the distribution system were normally observed after filter cleaning procedures and it is probable that these were accepted on that basis. In any event, on November 6, the first patient, a six-year-old boy, was admitted to the Elliot Community Hospital in Keene, suffering from severe and recurring nose-bleeds. High fever, nausea and vomiting were also present. Subsequently, between November 10 and November 14, four more patients were hospitalized, all running high fevers with other symptoms ranging from headache and general malaise to chest and abdominal difficulties. Preliminary agglutination studies were performed on these patients and the results were such that the physicians involved were strongly suspicious that they were dealing with typhoid fever. During the next several days the remaining nine of the fourteen recognized cases of typhoid developed and by subsequent questioning, it became apparent that all began to experience their symptoms between November 6 and 19.

On November 22, the Keene Health Department notified Dr. Edward W. Colby, State Health Officer, of the presumptive diagnosis of typhoid fever and requested assistance of the State Department of Health. From that time on, the investigation was performed jointly by State and local authorities and the Epidemic Intelligence Service of the U. S. Public Health Service.

The patients were interviewed extensively regarding the onset of illness, source of drinking water supply, milk supply, food supply, place of work, living conditions, previous family history of typhoid illness, etc. Literally every possible avenue which would disclose a common source of infection was explored inasmuch as

the pattern of onset of illness suggested a single source of infection. Further, it was estimated that the contamination would have had to take place some time between October 25 and November 2, taking into account the normal period of incubation for typhoid. The earlier date seemed more probable since one of the patients was found to have been out-of-state on October 31 and November 1. This assumption becomes a certainty when viewed in the light of the results of water examinations performed on samples taken on October 26.

The results of the field studies, conducted up to November 29, concerning the origin of infection are summarized in Dr. Alvin Novack's (U.S. Public Health Service) report, from which the following is quoted:

"1. Geographically, there was no direct relationship between patients.

2. Socially there was little or no association.

3. Only one or two families had been to any restaurant in the preceding six weeks.

4. The families were supplied by four different milk companies.

5. The families dealt with nine different food stores. Three or more families patronized the same store in four instances. Five families obtained their food from the same food store, the highest degree of correlation.

6. There were no known Salmonella Group D carriers in the area.

7. The only common denominator for all patients was the city water supply."

About this time reports were received concerning a water main break having occurred in the southern section of the distribution system during the latter part of October. Also, that the West Street gravel-packed well had been flooded and finally that there was a logging operation going on in the upper end of the Woodward Pond watershed. All three conditions were investigated with the first two being found to have no connection with the problem. The inspections made at the lumbering operation on November 30 and December 1 were very revealing. The

logging camp was occupied by three people and was located on a slope some 200 to 300 yards distant from the pond but draining away from it. Situated nearby was the barn housing two horses and all drainage took place toward a small intermittent brook about 125 feet away.

It was believed that the stream flow took place off the watershed but traveling along the course of the brook, it was found that final discharge was to Roaring Brook some quarter of a mile downstream of the pond. At the rear of the barn was an accumulation of five to six feet of horse and human excreta. There were no toilet facilities whatever and disposal of all wastes was to the manure pile. The three people at the camp were taken to the hospital for blood and stool examinations, the camp removed, the barn burned and the wastes completely removed from the area, after which the ground was liberally treated with chloride of lime. The stool culture from one of the men was shown to contain Salmonella group D organisms and he was presumably responsible for the outbreak. Meanwhile, chlorination of the supply was ordered, and installation was undertaken on December 2. Presently Stone Dam and Beech Hill water sources are being chlorinated separately. The permanent installation now in process of design will provide for a single plant on the supply main upstream of the point at which the line branches to the two filter plants.

To return to the matter of organism identification, examination by the local hospital laboratory disclosed the presence of Salmonella Group D cultures from either or both blood and stool specimens of all fourteen typhoid patients. These results were confirmed in the diagnostic laboratory at the State Hospital, Concord. For all practical purposes then, this information coupled with the data concerning the carrier employed in the lumbering operation, the extreme rainfall washing fecal material into the supply, the bacteriological results of water sampling during the period (see Table 4), the sudden onset of the disease and the timing of the filter cleaning were sufficient to demonstrate that the epidemic was caused by the public water supply. There remained one significant refinement or final step which would complete the epidemiological study, and this involved the

phage typing of cultures. Phage typing is a laboratory method whereby the individual strains of organisms within a single group may be specifically identified by means of a series of special agglutination reactions. These tests were conducted at the Enteric Bacteriology Unit, Communicable Disease Center, Chamblee, Georgia, and from this work it was apparent that all patients had been infected with an organism which is designated as *Salmonella typhi* Phage Type E. The same organism was recovered from the lumberjack carrier, which serves to complete the cycle and conclusively establish the common association between the fourteen typhoid cases and the carrier. So far as we know, this is the first time it has been possible to utilize an advanced technique of this type in tracing a water-borne outbreak of typhoid fever. Clearly, it has been an invaluable link in establishing the chain of evidence at Keene, even to the extent that the investigation may come to be regarded as a classic demonstration of the epidemiology of water-borne typhoid.

An interesting or unusual sidelight to the problem is the fact that relatively few cases were experienced. According to the U. S. Public Health Service authorities, it would be reasonable to have expected upwards of 180 to 250 cases of typhoid with the water supply as the vehicle of transmission. In our opinion, the fact that no such high incidence of cases occurred may be explained through the extremely high dilution which the rainfall of October 24 and 25 afforded. Secondly, the filtration facilities, although not operating at normal efficiency, did provide another barrier to the spread of the infection, and these two factors could readily account for the small number of cases. As concerns the final outcome of the incident, thirteen of the typhoid patients recovered from the illness and one death resulted because of other complications. A regular schedule of stool examinations is being maintained in order to evaluate the possible carrier problem. Developments from this study are gratifying inasmuch as the findings at the present time are all running negative. There is no practical method for determining whether or not subclinical cases occurred and, if so, whether carriers will develop from this source. Only time will provide an answer to this question.

Now as to what this unfortunate episode has taught us. One obvious thing is that the threat of intestinal water-borne disease is still very much a reality despite the general excellence of water supply quality which has been established over the years through the progressive efforts of water supply management, engineers and health authorities. Here we have an example where a rare set of circumstances were required to produce illness of epidemic proportions, namely, the carrier, torrential rains and a filter plant failure. The rarity of occurrence is verified by the fact that this lumbering situation existed on the watershed for well over a year without prior incident. Looking at the problem in a slightly different way, we can say with ample justification that there is still a real necessity for maintaining stringent watershed controls which has been the practice in New England and other regions of the country for a great many years. All of us have witnessed or participated in discussions where great emphasis is placed, by those who seek to open up water supplies to recreational or other use, upon the absence of disease and the "negligible" risk involved when multiple uses are permitted. The unhappy consequences of this approach is that we begin to stray immediately from the basic concept and purpose which prompted restrictions on use and a policy of controlled conditions in the first instance. Water-supply management has the fundamental responsibility of producing and maintaining a safe supply and, in view of this obligation, has no alternative to a carefully planned operation which is aimed at prevention. Health agencies operate within the same realm of responsibility and it should not be our purpose to provide a cure where there is an opportunity to prevent. In the final analysis, we in the water supply field are striving to come as close to 100% protection for the consumer as is reasonably possible of accomplishment.

With the knowledge that personnel, though conscientious, remain subject to error, and facilities are likewise capable of failure or inadequacy, it would seem that the only logical solution to the question of watershed use lies in the policy expressed by the American Water Works Association* and essentially

*Jour. A.W.W.A., vol. 50, no. 5, May, 1958, p. 580.

concurred in by the New England Water Works Association,† whereby recreational or other use of water bodies used directly as a source of drinking-water supply is rejected as an unsafe practice.

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City of Keene officials participating in the work were:

Joseph R. Bruce, Superintendent of Water Works Department
Joseph F. Burke, Superintendent of Public Works Department
Robert G. Shaw, City Engineer
Dr. Thomas Lacey, Chairman Keene Board of Health
Evan C. White, Health Officer
Donald E. Chick, City Manager

Actively associated with the studies from the State level were:

Dr. Edward W. Colby, State Health Officer
Dr. William M. Prince, Director, Bureau of Communicable Disease Control
Robert Miliner, Supervisor, Clinical Laboratory, N. H. State Hospital
Staff personnel from Division of Sanitary Engineering

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†Jour. N.E.W.W.A., vol. 72, no. 4, Dec., 1958, p. 355.

Appendix A

Statements of Policy Relative to Recreational Use of Public Water Supplies

*American Water Works Association**

Reservoirs may be classified as:

1. *Equalizing reservoirs*—reservoirs within the area served and delivering finished water ready for consumption to the distribution system.

2. *Terminal reservoirs*—areas providing end storage of water prior to treatment.

3. *Upstream reservoirs*—reservoirs providing storage of untreated water at various points in the watershed to provide or supplement the supply at the terminal.

Equalizing and Terminal Reservoirs

Policy: It is considered generally that recreational use of equalizing and terminal reservoirs and the adjacent marginal lands is inimical to the basic function of furnishing a safe and potable water supply to the system's customers, and should be prohibited.

Upstream Reservoirs

Impounded or stored water in upstream reservoirs can be classed in three categories:

Class A: Water derived from an uninhabited or sparsely inhabited area, at or near the point of rainfall or snow melt collected in a storage reservoir, clean and clear enough to be distributed to the consumers with disinfection only.

Policy: Safe practice in the water works field recognizes the necessity of permitting no recreational activity on the water and watershed lands in and about such storage reservoirs.

Class B: Water impounded from an area not heavily inhabited and allowed to flow from storage in a natural stream to the point of withdrawal and requiring treatment in varying degree in addition to disinfection.

Policy: Limited recreational activities on such reservoirs and adjacent lands are considered permissible under appropriate sanitary regulations.

Class C: Water which has flowed in a natural stream before storage for a considerable distance, having received polluting materials from municipalities, industries, or agricultural areas; confined in a reservoir primarily for purposes of storage until such time as low stream flow makes the stored water necessary for the use of the downstream city; and later allowed to flow from the reservoir to the tributary water works in an open stream accessible to the public; and requiring complete treatment.

*Jour. A.W.W.A., vol. 50, no. 5, May, 1958, p. 580.

Policy: Recreation is considered permissible under appropriate sanitary regulations. The determination of the kind and extent of recreational use shall be the sole responsibility of the water works executive of the system involved, whose primary obligation it is to provide a safe and potable water, and subject only to existing police powers.

Summary

The American Water Works Association registers its opposition to legislation permitting or requiring the opening of domestic water supply reservoirs and adjacent lands to recreational use. Control of water supply reservoirs must remain the prerogative of the water purveyor.

New England Water Works Association†

Whereas:

Man is a carrier of disease, and

There are reservoirs of infection still prevalent, and

Interstate and international travel is heavy, and

Man's natural immunity is constantly lessened by his excellent sanitary environment, and

Whereas:

Water is still a potential disease-transmission medium, and

The results of laboratory testing are so delayed as to allow infection of a community not protected by proper sanitary controls of its supply, and

Treatment facilities and processes are not completely infallible, and

There have been recent experiences of gross pollution of supplies, where recreation was allowed.

Now, Therefore, Be It Resolved:

That the New England Water Works Association opposes legislation or administrative action that will permit or require the opening of domestic water-supply reservoirs and adjacent lands to recreational use.

And Be It Further Resolved:

That the New England Water Works Association registers its approval of the policy to maintain the control of domestic water-supply reservoirs in the hands of the State Health Agencies and of the Water Purveyors and of the Consumers.

†This JOURNAL, vol. 72, no. 4, Dec., 1958, p. 355.

THE OZONATION OF WATER IN THE MONTREAL REGION

BY J. B. NOBERT*

[*Read September 21, 1960.*]

Surface waters are used more and more to supply and meet with the demand of to-day's growing towns and villages. These water resources have a very high potential as compared to ground waters, but in order to be safe for human consumption, they require an appropriate treatment and disinfection. The usual phases of this purification are aeration, flocculation, sedimentation, filtration and disinfection, or sterilization. Except for the disinfection process, the technique remains approximately the same in the water treatment plants, although some of the phases are omitted in some cases. Among the numerous sterilization processes known, chlorination and ozonation are used more extensively in the large-scale plants, such as the municipal waterworks.

The ozonation of water for public use is practiced in Western Europe since over half a century ago; the first plant was built in 1906 to be exact, at Nice, France. The first Canadian installation was started up in 1955 in the new water-filtration plant at the town of Sainte-Thérèse, located approximately 10 miles north of Montreal.

Since that time, five other town councils, impressed by the results obtained at Sainte-Thérèse plant, voted for the installation of this process in their waterworks. A total of five ozone-equipped filtration plants with capacities ranging from 0.6 to 7.5 million gallons of water per day are now in operation. These are as follows: Oka, 0.6; St-Eustache, 1.2; Ste-Thérèse, 3.6; L'Abord-à-Plouffe, 4.5; Pont-Viau, 7.5. The sixth plant at St-Joseph of St-Hyacinthe will start to produce around February, 1961. All the above ozone installations were built by "La Compagnie des Eaux et de l'Ozone" in Montreal. Ozone used

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in these waterworks gave a taste-free and odor-free water, where chlorine and activated carbon previously failed. These observations were made in two towns where the existing filtration plants, using chlorine and activated carbon, were enlarged to a greater capacity, and the ozone was introduced at the same time.

The writer took part in the design and the construction of these plants as a member of the Consulting Engineering firm in charge of the projects, and the following data and descriptions are based on observations made during the construction and the operation of these plants.

Physical and Chemical Properties of Ozone

As known, the ozone molecule is composed of three atoms of oxygen, it is unstable and will transform itself easily into oxygen. When purified, ozone is a sky-blue gas having an atomic weight of 48 and a density of 1.71. It liquefies into a very dark blue liquid at -112° C. It has a characteristic smell and is detectable in the air at a concentration of 1 in 10,000,000. Its solubility in water is in the order of a few parts per million at normal conditions. The decomposition of ozone is accelerated by the presence of hydroxyl ions or by an increase in the temperature.

Chemically speaking, ozone is a very powerful oxidizing agent that has the property of being transformed into free oxygen during the oxidation reaction. This is the reason why this disinfectant will not leave a chemical taste to the water once the sterilizing process is accomplished.

Description of the Process

Atmospheric air is used as the raw material for ozone production in waterworks, together with electrical power to transform part of the oxygen of the air into ozone.

One important factor that makes the ozonation process different from other known chemical disinfection processes is the fact that the raw material is free and also the disinfecting agent (ozone) is produced on the spot as needed and when needed.

This sterilizing process can be divided in three major parts:

First: The air conditioning

Second: The ozone production
Third: The contact of ozone with the water to be treated.

Air Conditioning

The atmospheric air cannot be used economically as such for the ozone generation on the industrial scale, the rate of production of an ozone generator being highly dependent on the moisture content of the gas. Dry air with a dew point of -40° F was found to be the most economical for producing ozone and no appreciable increase in yield was obtained in dryer air.

A silica gel or activated alumina desiccator produces air with the required physical properties for the purpose. Silica gel was chosen for its higher adsorption capacity by weight, hence, a longer cell life.

The desiccator is preceded by an air filter to remove any dust particles normally present in atmospheric air and to prevent the contamination of the desiccant. The filter paper layers acting as the filter medium are changed every three months.

During the summer months, when the moisture content of the air reaches higher values, it is more economical to dry the air using the combination of a cooling system and a desiccator. It was found that the moisture content of the air dropped by 66% in mid-summer, when the air is cooled down to 40° F in a cooling chamber by means of an electric refrigeration unit. It was also found that the useful life of a desiccator cell was constant with an inflow of air containing always the same amount of water per cubic foot.

The desiccator is composed of two cells (chambers), one being used while the other can be under regeneration or on stand-by. Each cell is calculated for a useful life of 24 hours before regeneration is needed. This regeneration, which lasts 3 hours, is obtained simply by blowing air heated at 260° F through the desiccant, to chase out the water absorbed on the surface of the silica gel. The cell is cooled down to room temperature before it is ready to be put back in the line.

After five years of service, the silica gel is still in very good shape, and it is not easy to foresee when this material will have to be renewed. The regeneration is semi-automatic in the Cana-

dian installations, but it could easily be made fully automatic, as is the case in Switzerland, by means of time switches and thermocouples.

Ozone Production

The five Canadian installations known to the speaker are equipped with the plate type ozone generator as invented by Mr. M. Otto. This ozone generator contains a certain number of elements, each element being composed of two electrodes (high and low tension) with a dielectric in between. The dielectric is made of ordinary glass and is placed against the low tension electrode. The high tension electrodes are cooled by convection and the low tension electrodes are hollowed to allow the cooling by a continuous flow of water. Spacers 3mm thick are placed between the dielectric and the high tension electrodes to allow a passage for the dry air. All the electrodes and the dielectrics are square shaped with a hole in the center.

The air circulates from the edges to the center of each electrode where it reaches the collector channel formed by the holes in each electrode and dielectric. When an electrical potential in the order of 8,000 to 12,000 volts is applied between the electrodes, a violet glow appears between the dielectrics and at the same time part of the oxygen in the dry air is transformed into ozone. This phenomenon is called the silent discharge.

The ozone concentration in the air varies, depending on the air flow, its temperature and the voltage applied between the electrodes. Concentration between 6 and 13 grams of ozone per cubic meter of air were obtained in the above ozonator; it is understood that machines of the latest design will produce a highly concentrated ozone for some special uses in research.

The amount of air flowing through the ozone plant is approximately 1/3 of the volume of the water to be treated. The ozone systems are designed with enough flexibility to take care of the variation of the demand for different periods of the year.

The power consumption per gram of ozone produced in winter time is 16 watts as per data obtained in one municipal plant. During mid-summer, this value is increased by about 25%. The power consumption for the air conditioning and the

ozone generation of a 90-lb-of-ozone-per-day plant was calculated from experiments at 10.3 kw per lb of ozone for the winter season and 12.9 kw in the summer.

Application of Ozone to Water

Ozone is applied to water after the preliminary treatments of flocculation, sedimentation and filtration are completed. The pH of the water is then around 6.0 which is ideal for ozonation. The pH correction to equilibrium with lime water is applied only after the ozonation is completed.

The ozone treatment of the raw water would require much greater amounts of ozone for proper sterilization; the organic materials and the suspended solids being highly reactive with ozone. In the Canadian installations, ozone is applied to the water by the means of the so-called emulsifiers. This piece of equipment is based on the principle of the water injector where the water flow sucks in the ozonated air and the turbulency produces a very fine dispersion of gas in water. The total static head on the emulsifiers is close to 14 feet. The mixture is then passed through the dissolving pipe leading from the emulsifier to the contact chamber. Part of the ozone is dissolved in the water according to the Rothmund coefficient of distribution. As the soluble part is used up in the reaction, it is replaced according to the Rothmund distribution coefficient by the ozone present in the fine gas bubbles dispersed throughout the contact column.

The contact chambers are designed for a contact time of five minutes. The powerful disinfecting and oxidizing properties of ozone on microorganisms, organic matters, etc., are such that five minutes of contact is more than sufficient to obtain a complete kill of all the pathogenic germs and to oxidize the greater part of organics in the solution. The taste, the odor and even the color of the water are greatly improved.

The amount of ozone needed for the sterilization of water depends on the temperature, the physical properties and the chemical composition of the water to be treated. In the Canadian installations with a highly polluted water, Ottawa river for instance, the ozone consumption varies during one year from

one to two parts per million by weight with 1.20 as a good average for the year.

For new installations, the exact quantity of ozone necessary to do the job can be determined experimentally with a portable pilot plant. Usually a complete chemical analysis study of the raw water is sufficient for the design of a plant.

An excess of ozone must be present at the outlet of the contact chamber in a properly designed system. This excess is a proof of the sterility of the treated water and the presence of ozone is checked regularly by the plant operator using the characteristic blue color reaction of potassium iodide and starch in the presence of ozone.

Nowadays an electrical method has been developed to measure continuously the residual ozone in a solution. This new piece of equipment can be equipped with alarms to signal the operator when an increase of the ozone production is required.

This increase is obtained simply by changing the potential between the electrodes. This is done by turning a contact switch connected to the primary taps of the step-up transformer without stopping the ozone production. The excess ozone will not produce any chemical taste to the finished product. It is slowly transformed back to oxygen and evaporates to the atmosphere from the clear well without the formation of chemical compound.

Results Obtained

Negative results of the microbiological tests carried out each day by the Quebec Provincial Health Laboratories on samples of water from each town, are a proof of the good efficiency of the ozone treatment in this province. All pathogenic or saprophyte germs usually present in surface water are perfectly destroyed by ozone.

The ozonation does not form addition products with the organic compounds found in the surface waters. Ozone will more likely oxidize and lower the organic content of the treated water thus making it less susceptible to further microorganism attack. The organoleptic properties are greatly improved by the aeration and the strong bleaching power of ozone. All traces of odor and bad taste caused for instance by the algae, plankton,

etc., are eliminated. Phenolic and aromatic compounds are oxidized by ozone with the eventual destruction of the ring structure (1).

Doctors Kessel, Allison, Moore and Kaine of the Bacteriological Department, School of Medicine of the University of Southern California proved experimentally that ozone destroys the poliomyelitis virus in a matter of minutes (2). In their experiments, they used a virus which caused poliomyelitis on monkeys in every case. The virus solutions were subjected to ozone by bubbling for periods varying from a few minutes to several hours. After the excess of the sterilizing agent was neutralized, the monkeys were then inoculated with the virus. The following results were obtained:

With an ozone residue of 45 to 50 hundredths of a milligram per litre, the virus was sterilized almost instantaneously, that is, a period not exceeding 2 minutes.

In 1947, Torricelli, laboratory chief of the Federal Service of Public Health at Berne, Switzerland, published an important paper entitled "The Instantaneous Disinfection of Drinking Water by Ozonation" (3) giving the results of his experiments with oxone. He demonstrated the undeniable superiority of ozone, particularly from the standpoint of its rapid action and of its organoleptic qualities. The odor, taste and even color of the water are actually improved owing to the high oxidation potential of ozone. Finally, Torricelli observed that ozone had a great sporicidal action and could destroy the charcoal bacteria spores after 25 hours of contact.

Economics

1. *Cost of installations*

As normally expected, the average cost of the installation per million gallon capacity drops as the plant capacity increases. Three years ago, the installation cost was close to $25,000.00 for a one million gallon capacity plant and the average cost per million gallons dropped to approximately $10,000.00 for a 7,500,000 gal. per day plant.

2. *Operation cost and maintenance*

The operation cost depends mostly on the electrical power rates in a particular region. In the Montreal region where the hydro-electrical power is abundant and the electrical power rates relatively cheap the cost of the power for the ozone section was calculated at $1.30 to treat 1 million U.S. gallons of water in a plant of 4.6 million gallons per day of capacity.

The ozone plant does not require any extra personnel, the supervision being included in the regular duties of the filtration plant operators.

The maintenance cost of the ozone system is low for the following reasons:

First: The system operates at atmospheric pressure or very near. Only a low-pressure air-circulation fan is used ahead of the air conditioning section, to overcome the air friction through the desiccator (a few inches at the most).

Second: The desiccator, the ozone generator and the emulsifiers are considered as static equipment without any mechanical moving part and do not require any special maintenance besides a periodic cleaning and painting.

The electrical refrigeration unit is the only piece of equipment having mechanical moving parts that will require a little more attention together with a periodic oiling, greasing and cleaning.

Conclusions

All five Canadian installations now in operation treat water from the Back river or Des Mille Iles river, both tributaries of the Ottawa river. Results from a recent survey showed these rivers to be among the most polluted of this province. Nevertheless, these five filtration plants still produce a treated water of the very best quality as compared to any other fitration plant.

The ozone system might look a little elaborate on first sight, but its flexibility and simple controls make it a routine job for the operator, once he knows the schedule of the operations.

The process is safe and effective from every standpoint, these are the main reasons why its use has spread across Europe

during the last fifty years and the constant growth in the number of the Canadian installations is a forecast of a promising future in this country.

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MAJOR VALVE-REPLACEMENT PROGRAM IN BRIDGEPORT, CONNECTICUT

BY KENNETH E. BENDER*

[*Read September 21, 1960.*]

Many of the older cities in the United States are faced today with major maintenance and replacement programs. In the center of large, busy industrial cities a major undertaking such as the replacement of valves on principal trunk lines presents a serious problem. To accomplish this type of work, with a minimum of inconvenience and a maximum of protection in the high-value business districts, is one of the most important jobs of the water works operators. It is the intent of this paper to describe how this problem was met effectively, efficiently, and economically in Bridgeport.

Bridgeport Hydraulic Company is a private water company serving seven cities and towns in lower, western Connecticut. The system serves, in addition to the City of Bridgeport, the towns of Fairfield, Stratford, Trumbull, Easton, Shelton, and Westport, comprising a population of approximately 300,000 people. The average daily consumption in this system during 1959 averaged 48 million gallons per day. The total number of miles of main in this system is approximately 900. Main sizes throughout the system vary from 4 in. to 48 in. in diameter.

Bridgeport as a city is important as a manufacturing center. The industries are widely diversified and extensive. Some of the more important products include machinery, electrical appliances and supplies, sewing machines, typewriters, firearms, ammunition, cutlery, plumbing supplies, hardware, iron and steel products, aircraft production, home appliances, automotive parts, and accessories. Transportation facilities are furnished by the New York, New Haven & Hartford Railroad, numerous motor freight lines and coast-wide shipping. Automotive transportation facilities include the Merritt Parkway, which skirts the city on the

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northern edge, and the recently completed Connecticut Turnpike, which passes just to the south of the highly concentrated business section.

Basically, the Bridgeport Hydraulic Company's system is gravity supply. The supply is impounded in five main reservoirs, north and northwest of the city and delivered through long pipe lines from each of three distributing reservoirs to the distribution system. Elevations throughout the system range from sea level to approximately 600 feet above sea level.

Most of the distribution system in the downtown Bridgeport area is at least 50 years old, and it was in this section that a major valve replacement program was undertaken in the spring of 1958. Through a periodic valve inspection and testing program, it was discovered that several of the mainline valves in the principal business area were defective for one reason or another and could not be relied upon to hold water in the event of a major break. Therefore, it was decided that a complete engineering study would be conducted in this particular area to ascertain which valves were defective and plan a program that would efficiently and economically provide for the replacement of these valves.

During January of 1958, the Pitometer Associates of New York were retained by Bridgeport Hydraulic Company to conduct various tests and investigations throughout the system. One particular phase of the investigations was to work through the downtown section and prove, by actually making complete shut-outs between mainline valves, those valves which were defective and would not hold water. This work was conducted during the winter months, when consumption was at an absolute minimum, and it was further carried on between the hours of midnight and 5:00 a.m. This time was selected, of course, in order that a minimum of inconvenience would occur to our customers. Upon completion of this particular investigation, it was found that four 24-in. valves, three 8-in. valves, and one 6-in. valve required replacement.

The first obvious solution to a condition such as this would be to install new valves in the existing lines under pressure, and then merely abandon the existing valves. This work could be carried on with no interruption in service whatsoever. On this

basis, a complete study was made of the various underground facilities within the street near the points where the existing valves were located. Locations of the various facilities; gas, sewer, electric, telephone, etc., were located and actual test pits were dug to determine if space would be available for inserting valves under pressure. In order to insert 24-in. valves under pressure, they must be installed horizontally and there must be approximately 13 feet clear distance from the back of the main to the point where the cutting equipment is used. Thorough investigation revealed that there would be no possibility whatsoever of installing valves under pressure, and therefore, it would be necessary to shut the area down and remove the defective valves and replace them with new ones.

Now that the objective had been thoroughly identified, it was necessary to test the valves that would be required to shut off the section in order to effect the repairs. This work was also carried on during the night hours and a complete trial shut-out was made exactly in the manner that it would be done when we were ready to start work on the replacement program. Once this phase of the work was completed and we knew definitely that it would be possible to effect a complete shut-out, we immediately started making plans to determine the number of customers that would be involved and how many would require temporary service lines during the operation.

The Distribution Engineer's office prepared detailed maps showing the entire area that would be affected. The maps indicated the mains in the street and the exact valves that would be closed, and, after being printed, were forwarded to the Service Department and the Inspection Department. These two departments collaborated to compile a listing of every customer that would be affected. The final listing indicated that 457 customers would be involved and it would be necessary to close 64 valves which would put 38 hydrants and 14,700 feet of main out of service, affecting 38 blocks. It should be noted that since this work was taking place in the principal business district, several hotels, restaurants, theatres, stores, multiple dwelling units, and various other commercial establishments were involved. In view of the large number of customers affected and the

tremendous number of valves that would have to be closed, it was decided that the job should be broken into two sections. When the plans had progressed to this point, contact was then made with the Fire Department of the City of Bridgeport, the National Board of Fire Underwriters, and the New England Fire Rating Association. All of the agencies that were to be involved were fully appraised of the situation and they were given maps showing the valves that would be shut, a list of the customers that would be out of water, and a list of the hydrants that would be off duty. After consultation with the various authorities, it was decided that the first phase, which would occur in the heart of the downtown business district, would take place on a weekend. With this date in mind, we prepared to notify each customer at least one week prior to the actual shut-out, and where necessary, make arrangements for a temporary supply to be provided. The notification work and temporary service line work was conducted by the Inspection Department and the Service Department.

On phase #1, it was necessary to remove and replace two 24-in. valves, three 8-in. valves and one 6-in. valve. To prepare for the actual shut-down and removing the valves, excavations were started on the Tuesday preceding the weekend that the work was to be done. Special police protection, of course, was required for traffic control. As the excavations were completed and the spoil material removed, Wachs Pipe Saws were set up on the mains, and the excavations were planked over in order that a minimum interference to traffic would take place. On Friday, 2-in. taps were installed on both sides of the defective 24-in. valves. This was a precautionary measure in the event that a perfectly tight shut-off could not be made, and it would also facilitate the draining of the line. On the same day many of the small valves were closed in order to save time on Saturday night. Careful consideration was given to the selection of these particular valves in order that fire protection and domestic supply would not be curtailed.

On Saturday night, at 11:00 p.m., two gate trucks equipped with Payne-Dean valve operators reported to the Distribution Engineer and commenced closing the balance of the smaller

valves. At approximately midnight, the remainder of the work crews and equipment operators reported to the scene of activity where they began to set up the necessary equipment that would be used. Between 11:00 p.m. and 12:00 midnight, the Bridgeport Fire Department personnel reported to the scene and liaison was made between the Fire Department, Police Department, and Bridgeport Hydraulic Company. A temporary headquarters was established at one of the main intersections and through radio, direct communication was possible between any one of the three groups. By means of radio, the Fire Department was able to keep track of the valves as they were closed, and they in turn proceeded to identify each hydrant that would be off duty by attaching a red lantern to it. This was obviously required in the case where a hydrant was on a corner, or where there were two parallel mains in the same street and one main would be in service, while the other main would be out of service.

At midnight, as previously mentioned, the Fire Department along with the Police Department reported for duty. A walking fire patrol comprised of 50 firemen and policemen patrolled the entire downtown area and kept it under strict surveillance while the section was without water. The fire patrol was augmented by plain-clothes detectives and plain-clothes members of the National Board of Fire Underwriters. The Fire Department had made very extensive plans as to how they could cope with any fire in the section shut off. Additional equipment was moved in from outlying firehouses in order to assist if necessary.

The maximum allowable time allotted for the work in this section was a ten hour period, from 1:00 a.m. Sunday morning to 11:00 a.m. Sunday morning, and time was of the essence.

To expedite de-watering of the mains involved, 2-in. pumps were set at the location of each of the 2-in. taps, and three 4-in. pumps were attached to fire hydrants. The remaining valves were closed at 1:00 a.m. and as soon as we were positive of a complete shut-out, the hydrants at the higher elevations were opened to permit air to enter the line and the various pumps were started to pull the water from the mains. When the head was relieved and the de-watering process was under way, the pipe saws were started and the job proceeded according to plan. As

the pipe was being cut at the various locations, the new gates to be installed along with the necessary nipple pieces that had already been poured into the gates were being brought to the job. The saws were making cuts at predetermined points so that it would merely be a matter of lifting the defective gate with a nipple on each side of it and dropping in a new unit with two solid sleeves. From this point on the entire job was merely a matter of routine.

A total of 25 men comprised the field crews that were involved in the removal and installation of the six valves on phase #1. All work was completed, water service restored, lines cleared of air and flushed, by 10:30 a.m. on Sunday morning, ½ hour before the time limit.

Phase #2, which was somewhat smaller and easier to handle in that only two 24-in. valves had to be replaced, was handled in exactly the same manner on the following weekend with the same amount of success.

The 24-in. valves that were removed from service were returned to our Construction Yard, where they were cleaned and examined by a representative from our valve supplier. This examination indicated that two of the four 24-in. valves could be rebuilt at a relatively minor cost, and accordingly, these two valves were returned to our supplier where new seat rings were installed and the valves were completely overhauled and reconditioned. When these valves were returned they were placed in stock for use at other locations.

Perhaps the most important point that should be stressed in this paper is the fact that a periodic valve inspection and testing program is a *must* in the modern-day water-works operation. However, to merely operate a valve part way or even close it fully is not the ultimate answer. Inspection and operation in this particular manner is certainly commendable, however, it does not prove "beyond the shadow of a doubt" that the valve will close tightly and will hold water in the event of an emergency. The author firmly believes that in all major trunk mains periodic shut-outs should be made between each mainline valve. This serves several purposes, namely: proving that the valves are operating effectively; that there is little or no leakage existing;

it checks the condition of the side valves; it proves that the check valves on large private installations or elevated tanks are functioning properly; and determines if any unknown cross-connections may exist. In addition to the benefits described from a program of this type, it also provides a dress rehearsal for the personnel responsible for closing large gates and shutting out major mains in the event of an emergency. The valve operators and the distribution personnel become familiar with each major portion of the trunk lines and know how to close it off with a minimum of delay.

I mentioned earlier that we considered the possibility of installing valves under pressure. This would have been the most satisfactory method of accomplishing this work, and certainly far less planning, inconvenience, and risk would have been entailed. The final cost analysis indicated that it would have only cost approximately $8,000 more to install these same valves under pressure. Aside from the cost, we are now secure in the knowledge that we can control breaks in the high-value areas of the city.

Mr. John Murdock, Jr., published a paper in the August, 1957, issue of the A. W. W. A. Journal which dealt with the problem of court opinions on pipe-line breaks. In his paper he stated, "When a break occurs, the well trained water works man does all in his power to mitigate damage. The courts have often absolved the water agency of liability for the break, but have held it liable for damages because of delay in shutting off the water." This is a point that should be carefully considered by all of us.

There is no doubt that many citizens slept soundly and peacefully throughout the entire project. So far as Bridgeport Hydraulic Company knows, no one in any hotel was without water, and no one who required water for the operation of equipment was forced to take any emergency measures. We feel that it was only through careful planning and engineering that a job of this size could be conducted with such a small amount of interference to any of our customers.

AUTOMATIC OPERATION OF UNATTENDED PUMPING STATIONS

BY J. A. ANDERSON*

[*Presented Sept. 21, 1960.*]

Because the automatically operated, unattended pumping station is becoming commonplace, this is a timely subject. With the trend to suburban living, residential water demand has increased and become more widely dispersed. Not only has a residential shift taken place, but industry also, with its large demands on our water facilities has moved to the country. This has necessitated commensurate expansion of pumping facilities. These smaller stations are used for boosting pressure at needed points, as well as bringing new water sources on the line.

With the increase in number of such stations, and with the advent of automatic control systems and equipment, these stations are generally unattended, thus providing high efficiency and economy of operation. In this presentation we are concerned with the power part of the pumping station. There are specialists in the field of automatic level and pressure control, telemetering, etc., who are important in the operation of the station, but do not enter into certain protective aspects of the power equipment.

In considering the motor and control problems of this type of station, generally the following conditions exist:

1. The station is unattended.
2. It is located on the outskirts of the city or town.
3. It is usually at the end of a relatively long power transmission line.
4. It frequently has no means of communication.
5. The electrical load is usually one or more large motors which represents special problems on the long transmission line.

With the existence of these conditions, and assuming no other problems of operation generating from pilot device troubles

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or mechanical troubles, the power equipment may be subjected to one or more of the following hazards:

1. Lightning.
2. Running overload condition.
3. Single phase operation in a 3-phase system.
4. Short circuits.
5. System instability.

Lightning striking a unit of this type has frequently caused burn-outs of holding coils of contactors and relays of the controller. If such should occur, it means the motor will shut down and cannot restart until the trouble is cleared. It sometimes takes several hours for the discovery of this condition. Water pressure could drop in the time interval and other serious consequences could develop.

If the motor should stop due to an overload condition, the result would be the same even though the cause be different.

Many times a single phase condition on a 3-phase system develops when lightning destroys a primary or high voltage fuse. When this happens, it is not unusual for a motor which is running, to continue to run, but when it shuts down from some automatic cycle and tries to restart on single phase, it is another matter. A 3-phase motor will not start on single phase. High currents in the remaining lines to the motor result and the motor is likely to burn out. Single phase conditions are just about the worst case of unbalanced voltage of a 3-phase system. However, currents in the three phases of any motor are frequently unbalanced due to only slight amounts of voltage differences between the three phases. Our tests show this condition equally dangerous because under some conditions only a 3% difference between phases of a 3-phase system will produce as much as a 25% difference in phase currents. A current that is 25% higher than normal flowing in one of the phases of a 3-phase motor could easily produce a motor burnout.

Short circuits in either the motor or controller obviously are dangerous but many times a single fuse blowing results in a single phase condition, again with many of the results just outlined.

Over-all system instability is perhaps the most subtle problem. It is usually temporary in nature, and therefore hard to detect; at the same time produces perhaps the most serious consequences of any of the problems. As stated previously, the electrical load in a pumping station is usually a single large load—the motor. When the motor is started, it adds a considerable load on the power lines. Because of this, it becomes extremely important to adequately protect the electrical equipment within the pumping station as well as the equipment connected to the transmission line external to the station. Also, preventing transmission line protective devices from tripping needlessly is equally important.

Because of the location of the stations on power transmission lines, two serious conditions can develop and affect the operation of the station.

First, the power system may become unbalanced and the conditions then exist as previously described. Second, a serious condition occurs when the service is completely interrupted and the system is idle for a period long enough for lamps to become cold, and appliances such as refrigerators, service pumps, heating units, etc., stopped long enough for their automatic control devices to demand operation. With this condition existing, the effect on the system upon re-energization from the source is practically the same as that of a short circuit with all the lights and appliances connected simultaneously; the line voltage will be pulled down to an abnormally low value with the possibility of the primary and secondary protective devices tripping out.

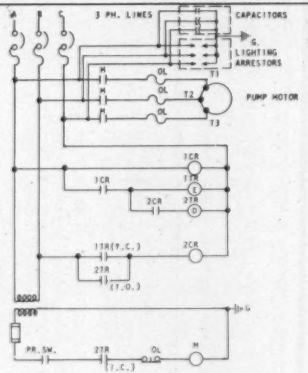
Now if the pump motor also tries to start at such a time, along with the other maximum loads on the service line, the starter may telegraph with unsatisfactory results and defeat the protective operation of an overload relay. Moreover, under such conditions, contact welding, at times, has taken place with further disastrous results. Fortunately, we have the means to deal with these problems in a highly satisfactory way. Standard starters can be provided with the necessary short circuit protection as required by the system. Use of the 3-coil overload relay in the motor starter provides overcurrent running protec-

tions for the motor under all conditions. Also, the 3-coil overload relay offers protection against motor burnouts due to unbalanced supply voltages, open phase conditions, and unbalanced loading of 3-phase supply lines. Satisfactory lightning arrestors should be used. They are inexpensive and offer adequate protection for the equipment against this hazard.

In addition to the above protection available, we are now offering another type of protection designed to provide system protectiton in that the pumping equipment in the unattended pumping station will not be permitted to operate unless favorable voltage conditions exist. We are offering as a solution for this problem of operating with unstable voltage conditions, a two-voltage relay scheme, which when used in the control circuit of the pump motor starter, will prevent operation of the starter in case a phase is open; also which will require a minimum of 90 to 95% of full voltage on the system and a time period imposed on the starter, before a start can be attempted following a power outage. If, therefore, the line regulation is poor, and upon closure of the starter the voltage should drop to, say 50 or 60% of normal voltage, the voltage relays will drop out and open the starter control circuit. Then the timing relay will maintain the control circuit open for a definite period. Normal voltage is again restored, before a second start can be attempted. A second timing relay is used to prevent nuisance shutdown of the equipment due to momentary line dips in voltage.

Therefore, in case of a system failure with resultant shutting down on all machines, lamps, etc., in service, a time delay period is imposed on the pump motor starter for a long enough period to allow the power system to get other loads started after restoration of voltage, before the pump motor is added. This contributes to the stability of the system and also insures against undesirable misoperation of the pump motor starter. The elementary diagram of this control scheme is shown in Figure 1.

The advantages of this proposed equipment are that additional protection can be provided with the use of standard available components that are well designed and tested and field proven; and because of this, pumping station control can be obtained at the lowest possible cost.



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DESCRIPTION OF OPERATION.

WITH NORMAL CONDITIONS IN THE SERVICE LINES AND THE BREAKER CLOSED, THE VOLTAGE RELAYS AND TIMING RELAYS WILL CLOSE IN SEQUENCE AND 2TR,(T.C.) WILL BE CLOSED SO THAT WHEN THE PRESSURE SWITCH (OR CONTROL DEVICE) DEMANDS OPERATION THE PUMP MOTOR WILL BE STARTED.

IF ONE PHASE IS OPEN ONE OF THE CR RELAYS WILL BE OPEN AND THE MOTOR CANNOT BE STARTED.

IN EVENT OF A SYSTEM VOLTAGE FAILURE ALL RELAYS AND "M" CONTACTOR WILL OPEN AND THE MOTOR WILL STOP. WHEN SERVICE IS RESTORED AND THE SYSTEM VOLTAGE REACHES 90 TO 95 PERCENT NORMAL VALUES RELAY 1CR WILL CLOSE AND ENERGIZE RELAY 1TR WHICH IS TIMED CLOSING THUS ALLOWING OTHER POWER LOADS ON THE SYSTEM TO BE BROUGHT UP TO SPEED BEFORE 2CR AND 2TR RELAYS CLOSE TO START THE PUMP MOTOR AND ADD ITS LOAD TO THE SERVICE LINES.

IF THE SYSTEM FAILURE IS MOMENTARY, THE TIMED OPENING PERIOD OF RELAY 2TR (T.O.) CONTACT WILL NOT PERMIT IT TO OPEN SO WHEN NORMAL VOLTAGE IS RESTORED THE MOTOR WILL RESTART AT ONCE. IF THE REGULATION IS POOR AND THE INRUSH PULLS THE LINE VOLTAGE DOWN TO 50 PERCENT THE RELAYS WILL ALL OPEN AND SHUT DOWN THE MOTOR. IT THEN CANNOT ATTEMPT TO RESTART UNTIL THE SYSTEM HAS AGAIN REACHED 90 TO 95 PERCENT NORMAL VOLTAGE AND THEN WILL STILL BE DELAYED IN STARTING FOR THE INTERVAL OF TIME SET FOR THE 1TR RELAY.

SET 1TR (T.C) TO CLOSE IN 5 SECONDS OR MORE AFTER ITS COIL IS ENERGIZED. THIS ALLOWS TIME FOR THE SYSTEM TO RECOVER AND STABALIZE OTHER LOADS RUNNING. SET 2TR (T.O) TO OPEN IN ONE SECOND AFTER ITS COIL IS DE-ENERGIZED. THIS KEEPS THE CONTACT CLOSED ONLY LONG ENOUGH TO ALLOW THE PUMP MOTOR SPEED TO FALL TO THE MINIMUM ACCEPTABLE RESTARTING SPEED.

CONNECTIONS FOR PUMP MOTOR CONTROL FOR UNATTENDED PUMPING STATION.

	APPROVAL	SIGNS	ZONES
A		—	
B			
C			
D			
E			
F			
G			

DRAWN D. BEILEY 11-23-59
TRACED
CHKD
SUPV
BUY NO.
BUY BY NO.
PANEL NO.
ORDER NO. MN37866 BILL NO.

CUTLER-HAMMER

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3501

FIG. 1

PROCEEDINGS

November 1960 Meeting

Statler-Hilton Hotel, Boston, Mass.

Thursday, November 17, 1960

President Kenneth W. Robie in the Chair.

Secretary Knox announced the election of the following new members:

Paul T. Bowen, Mechanical Engineer, Jenks and Ballou, Providence, R. I.; Daniel J. Hess, Jr., Sales Engineer, The Permutit Co., Needham, Mass.; John R. Anderson, New England Fire Insurance Rating Association, Boston, Mass.; Edward J. Odell, Commissioner of Public Works, Natick, Mass.; Robert B. Taylor, Student, Tufts University, Medford, Mass.

Junior Member:

Arthur F. Evans, Student, Tufts University, Medford, Mass.

Associate Members:

Infilco, Inc., Tucson, Ariz. (reinstated); Orangeburg Manufacturing Co., New York, N. Y.

A paper, "Grading Water Systems," was read by John R. Anderson, New England Fire Insurance Rating Association, Boston, Mass.

A paper, "An Experimental Study of Powow River Water and Water from the Powow River Wells of the Town of Amesbury for Color and Iron Removal by Means of a Pilot Plant," was read by Robert A. McCracken, Senior Sanitary Engineer, Massachusetts Department of Public Health, Boston, Mass.

DECEMBER 1960 MEETING

STATLER-HILTON HOTEL, BOSTON, MASS.

THURSDAY, DECEMBER 15, 1960

President Kenneth W. Robie in the Chair.

Secretary Knox announced the election of the following new members:

Alexander A. Adams, Foreman, Water Department, Stoughton, Mass.; Donald Atkinson, Superintendent of Public Works, Sharon, Mass.; Gerard DiFiore, Chairman, Kent County Water Authority, West Warwick, R. I.; James A. Johnson, Principal Engineer, J. A. Johnson & Associates, Boston, Mass.; R. Ernest Leffel, Sanitary Engineer, Camp, Dresser & McKee, Boston, Mass.; Charles A. Parthum, Project Engineer, Camp, Dresser & McKee, Boston, Mass.

Associate Member:

Virginia Erection Corp., Pittsburgh, Pa.

A paper, "Water-Borne Diseases," was read by Dr. James C. Hart, Director of the Division of Preventable Diseases, State Department of Health, Hartford, Conn.

A paper, "Needham and Marlborough Connections to the Metropolitan District Commission Water System," was read by Robert T. Koopman, Project Engineer, Metcalf & Eddy, Boston, Mass.

JANUARY 1961 MEETING

STATLER-HILTON HOTEL, BOSTON, MASS.

THURSDAY, JANUARY 19, 1961

President Kenneth W. Robie in the Chair.

Secretary Knox announced the election of several new members:

Kenneth O. Hodgson, Sales Representative, R. D. Wood Co., Newtonville, N. Y.; Leonard E. Phelon, Superintendent, Water Department, Westfield, Mass.

Associate Member:

Solvay Process Division, Allied Chemical Corp., Boston, Mass.

Reinstated Associate Member—Joseph Dixon Crucible Co., Jersey City, N. J.

A paper, "The Challenge of the Sixties to the Water-Utility Office," was read by Richard G. Small, Assistant Treasurer, Portland Water District, Portland, Me.

A paper, "Will Increasing Recreational Demands Require Changes in Protective Policies for Public Water Supplies?," was read by Charles H. W. Foster, Commissioner, Massachusetts Department of Natural Resources, Boston, Mass.

PERSONNEL OF COMMITTEE WHICH PREPARED TENTATIVE AWWA STANDARD FOR FABRICATED ELECTRICALLY WELDED STEEL WATER PIPE

The accompanying "Tentative AWWA Standard for Fabricated Electrically Welded Steel Water Pipe" was prepared by Water Works Practice Committee 8310D, whose personnel was as follows:

H. ARTHUR PRICE, *Chairman*
W. W. HURLBUT, *Chairman Emeritus*

Consumer Members

H. K. ANDERSON
ABRAHAM BROWN
G. E. BURNETT
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C. J. GINDER
C. B. HARDY

AWWA C201-60T

American Water Works Association

TENTATIVE

AWWA STANDARD

for

FABRICATED ELECTRICALLY WELDED STEEL WATER PIPE

This "Standard for Fabricated Electrically Welded Steel Water Pipe" is based upon the best known experience and is intended for use under normal conditions. It is not designed for unqualified use under all conditions and the advisability of its use for any installation must be subjected to review by the engineer responsible.

First Edition approved Apr. 25, 1940; Second Edition approved as "Tentative" May 15, 1960.

AMERICAN WATER WORKS ASSOCIATION
Incorporated
2 Park Avenue, New York 16, N.Y.

Prepared by

Water Works Practice Committee 8310 D

Acknowledgment is made and appreciation is expressed to the Subcommittee on Pipe of the Steel Water Pipe Manufacturers Technical Advisory Committee for its assistance in the preparation of this standard. The officers of this committee are R. C. Beam, chairman; Walter H. Cates, secretary.

Latest Revisions to C201

This Second Edition of AWWA Standard C201 was approved as "Tentative" on May 15, 1960. The principal change involved is that this edition covers fabricated electrically welded pipe of all sizes, whereas the First Edition covered only sizes 30 in. and larger.

Designation: As a result of the revision, the former designation, "C201–59," has been changed to "C201–60T."

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Appendix

Intermediate-Strength Steel Plate A1
Physical Data A2

AWWA C201–60T

Tentative AWWA Standard for

Fabricated Electrically Welded Steel Water Pipe

Section 1—General

Sec. 1.1—Scope

This standard covers the manufacture of fabricated straight butt seam or spiral butt seam electrically welded steel pipe intended for the conveyance of water, or other special sections which are required for closures, curves, or changes in alignment or grade to meet special conditions. For the purpose of this standard, fabricated pipe shall be defined as steel pipe fabricated from plates or sheets; the properties of the material are determined prior to fabrication.

Sec. 1.2—Definitions

Under this standard the following definitions shall apply:

1.2.1. *Purchaser:* A person, firm, corporation, or governmental subdivision entering into a contract or agreement for the purchase of any materials or for any work to be performed.

1.2.2. *Contractor:* The person, firm, or corporation executing the contract or agreement with the purchaser to furnish any material or perform any work.

1.2.3. *Inspector:* The inspector or those assistants of the purchaser properly authorized and limited by the particular duties entrusted to them.

1.2.4. *Fusion welding:* The process of welding metals in the molten, or molten and vapor, state without the application of mechanical pressure or blows.

1.2.5. *Root:* The zone at the bottom of the cross-sectional space provided to contain a fusion weld.

1.2.6. *Throat:* The thickness of weld along a straight line passing through the root, excluding weld metal above plate surface.

1.2.7. *Fillet weld:* A weld of approximately triangular cross section which lies in a plane disposed approximately 45 deg with respect to the surfaces of the parts joined. The size of a fillet weld shall be expressed in terms of the width in inches of one of its adjacent fused legs, the shorter if unequal.

1.2.8. *Butt weld:* A weld whose throat lies in a plane disposed approximately 90 deg with respect to the surface of at least one of the parts joined. The size of a butt weld shall be expressed in terms of its net throat dimensions in inches, excluding weld metal above plate surface. A double-welded butt joint is one in which the

filler metal is added to both sides. A single-welded butt joint is one in which the filler metal is added to one side only.

1.2.9. *Flame cutting:* The process of severing metal by means of a gas flame.

1.2.10. *Nominal wall thickness:* The named or given thickness as distinguished from the actual or measured thickness.

1.2.11. *Spiral-seam fusion-butt-welded pipe:* Pipe in which the line of the fusion seam is a helix on the barrel of the pipe.

1.2.12. *Straight-seam fusion-butt-welded pipe:* Pipe in which the line of the fusion seam parallels the axis of the pipe.

1.2.13. *Resistance-welded pipe:* Pipe made by a series of operations in which the flat-rolled material is cold shaped into tubular form, and the union of the seam effected by the application of heat and pressure. The welding heat is generated at the seam by resistance to the flow of an electric current in a circuit of which the pipe to be welded forms a part.

1.2.14. *Ladle analysis:* The chemical analysis taken at the time the steel is being cast into ingots.

1.2.15. *Check analysis:* The chemical analysis taken from the skelp or plate.

1.2.16. *Coupon (weld coupon):* A pair of test plates of specified dimensions made from metal of the same specifications and thickness as the pipe wall, prepared for welding, and attached to a pipe shell being welded at the end of a longitudinal joint so that the edges to be welded in the test plates are a continuation of, and exactly similar to, the corresponding edges of the longitudinal joint. The pair of plates is then made into a single weld test specimen by having the weld metal deposited in the test plates continuously with the weld metal deposited in the longitudinal joint by the same technique.

1.2.17. *Girth seam:* A circumferential welded seam lying in one plane, used to join lengths of straight pipe or to join pieces of mitered pipe to form fabricated elbows or turns.

1.2.18. *Grade of material:* The designation given to a material according to its chemical analysis or physical properties.

Sec. 1.3—Supplementary Details to Be Specified by Purchaser

When purchasing pipe under this standard, the purchaser shall provide specific supplementary information regarding the following details:

1.3.1. Nominal inside or outside diameter of pipe.

1.3.2. Thickness of steel plate or sheet material.

1.3.3. Laying length of pipe sections.

1.3.4. Working water pressure for each thickness of pipe.

1.3.5. Hydrostatic test pressure for fittings.

1.3.6. The maximum number of longitudinal and girth seams for each pipe section.

1.3.7. Type of field joints (description or drawings).

1.3.8. Standard designation and grade of steel material required, as set forth under Sec. 2.1.1, or as otherwise specified.

1.3.9. All special sections, indicating for each component part the dimensions, the standard designation and grade of material required, the type of ends, and the required hydrostatic test pressure.

1.3.10. The drawings that are to be furnished by the manufacturer.

1.3.11. Qualification code for welders, if other than that set forth under Sec. 3.5.3.

Sec. 1.4—Inspection

1.4.1. All work done and material furnished may be inspected by the purchaser during all phases of manufacture and testing, but such inspection shall not relieve the contractor of his responsibility to furnish material and perform work in accordance with this standard.

1.4.2. The contractor shall notify the purchaser in advance of the production and fabrication of materials in order that the purchaser may, if desired, arrange for mill and shop inspection.

1.4.3. The inspector shall have free access to those parts of all plants that are concerned with the furnishing of materials or the performance of work. The contractor shall furnish the inspector reasonable facilities and space without charge for the inspection, testing, and obtaining of any information he desires concerning the character of material used and the progress and manner of the work.

1.4.4. The inspector may reject any or all pipe sections or special sections that are not of the material specified, that are not fabricated in accordance with the outlined procedure, or that do not conform to the prescribed test results, condition of pipe, and tolerances set forth in this standard, the approved drawings, and the purchaser's supplementary specifications.

Sec. 1.5—Materials and Workmanship

1.5.1. All materials furnished by the contractor shall be of the specified quality. All work shall be done in a thorough workmanlike manner by mechanics skilled in their various trades. All material furnished and all work done shall be in accordance with this standard.

1.5.2. Any plate, sheet, or fabricated pipe that reveals scars or injuries from hammering or other causes may be rejected. Any plate or sheet that develops irreparable defects during fabrication of pipe will be rejected. If structural defects, pits, or laminations are found in any material and, in the opinion of the inspector, cannot be corrected satisfactorily, the material will be rejected.

Sec. 1.6—Equipment

1.6.1. *General.* Manufacturer's equipment, such as for welding, flame cutting, or other operations, shall be of a standard and quality necessary to produce pipe meeting this standard. Equipment, in general, shall be in good repair and shall be modern, as judged by the standards of the industry.

1.6.2. *Arc welding equipment.* Generators and transformers shall be designed expressly for welding, shall be capable of delivering substantially constant current, and shall be adjustable through a range ample for the requirements of the work. They shall be provided with controlling devices and suitable meters showing the welding current and arc voltage at all times. Automatic welding heads with suitable auxiliary handling equipment to provide control of electrode speed and welding arc shall be subject to the requirements of this standard. Welding cable shall have sufficient conductivity to avoid inadequate voltage and current at the arc and shall be insulated sufficiently to avoid short circuits. Electrode holders shall provide clean surfaces in contact with electrodes and shall hold electrodes firmly as required by the welding process.

Sec. 1.7—Drawings

Drawings shall be the purchaser's drawings or the contractor's drawings approved by the purchaser.

Sec. 1.8—Testing

Pipe sections and special sections shall be tested as required herein. Steel material shall be subjected to the required mill test at the steel producer's plant or, at the contractor's option, a test of a specimen plate of the steel material will be made as stated in this standard. Tests of welding operators, tests of welded joints, and the hydrostatic test of finished sections shall be made as stated under Sec. 5 of this standard.

Section 2—Description of Pipe

Sec. 2.1—Steel

2.1.1. *Steel plate.* Steel plate shall be of Grades B, C, or D of ASTM A283 (Low and Intermediate Tensile Strengths of Carbon Steel Plate for Structural Quality), or as otherwise specified by the purchaser. Steel plate shall be ordered to a thickness with a maximum allowable variation of 0.01 in. less than the specified thickness. The inspector may witness manufacture and tests of plate at the mill and may required that the contractor furnish him test reports on each heat from which the plates are rolled.

2.1.2. *Specimen plates.* If requested by the purchaser, the contractor shall furnish specimen plates of the steel that will be used in the manufacture of the pipe. Specimen plates shall be of the size necessary to obtain the number of specimens required in the plate specifications, and the tests of the specimens will be made by the purchaser. If the specimens fail to meet the requirements of the specifications under which they were manufactured, a second test shall be made, and if all the specimens meet the requirements, the plate will be accepted, but if any of the specimens fail to meet the requirements, all plate furnished under the same heat number will be rejected. The contractor shall reimburse the purchaser for all expenses incurred in making a second test.

2.1.3. *Steel sheets and coils.* Steel sheets or coils used shall conform to the physical properties of Grade A material specified in the latest revision of ASTM A245 (Light-Gage Structural-Quality Flat Hot-Rolled Carbon Steel), or as otherwise specified by the purchaser.

Sec. 2.2—Pipe Dimensions

2.2.1. *Diameter.* The pipe diameter shall be the nominal inside or outside diameter as specified by the purchaser.

2.2.2. *Length of sections.* All straight pipe sections shall be of the length specified by the purchaser. The purchaser, in his request for bids, shall have the right to specify shorter lengths, which may be required for closures and proper location of any special section.

Sec. 2.3—Ends of Sections

Ends of pipe sections supplied under this standard shall be of the type specified by the purchaser in his request for bids. Available types are:

a. Ends for mechanically coupled field joints

b. Ends with slip joints (lap joints) for field welding

c. Plain ends or beveled ends for field butt welding

d. Ends fitted with butt straps for field welding

e. Ends for riveted field joints

f. Bell-and-spigot ends with rubber gasket

g. Plain ends fitted with flanges

h. Taper ends for driven field joints.

Sec. 2.4—Seams

Longitudinal seams, spiral seams, and shop girth seams shall all be butt welded.

Sec. 2.5—Special Sections

Curves, tees, branches, and other sections required for changes of alignment or grade which are made up of sections of straight pipe shall have the required type of ends, shall be manufactured from steel plate or sheet, cut, beveled, and formed to the required shape, or fabricated in accordance with the contractor's approved drawing. When such details are not specified, the angular change for welded plate specials shall not exceed 22½ deg per cut for curves or 45 deg for branches and wyes. Saddles, nozzles, or other fittings intended for connection to other pipelines and structures shall be of the required material and fabricated in accordance with detailed description or drawings furnished by the purchaser; or they shall be fabricated in accordance with the contractor's approved drawings.

Section 3—Fabrication of Pipe

Sec. 3.1—Preparation of Edges

Edges of plates and sheets to be joined by automatic welding shall be cut mechanically to the shape required for the particular welding process. Edges of plates or sheets to be joined by manual welding shall be formed to the shape required by the purchaser or in accordance with the contractor's approved drawing. The resulting edges for welding shall be uniform throughout the length of the plate or sheet and shall form a straight line.

Sec. 3.2—Lap Breaking and Forming

Before the forming of longitudinal edges, all plates or sheets shall be lap broken by a continuous rolling operation or in a press having dies that are machined to the proper radius of the pipe shell. The pressure exerted in the lap-breaking operation shall be sufficient to secure a true and uniform curve at the edges. Plates or sheets shall be formed to a true cylinder. Plates formed so as to require hammering in order to obtain the desired shape will not be accepted. After forming, all pipe surfaces shall be inspected for pits or laminations. The inspector may reject any defective plate or sheet or permit its resubmittal for inspection after the use of an approved method of reconditioning.

Sec. 3.3—Cleaning of Surfaces to Be Welded

All plate or sheet edges to be welded and surfaces adjacent to them shall be free of oil, grease, and rust.

Sec. 3.4—Fitting Up

No plate or sheet shall be fitted up until it has been approved by the inspector. The plates or sheets to be welded shall be accurately matched and retained in position during the welding operation. Tack welds may be used to hold the edges in line, provided the tack weld thickness will permit the

tack weld to be thoroughly fused with and become a part of the strength weld in the welding operation. The method employed shall produce a finished pipe having a circular cross section throughout its length.

Sec. 3.5—Requirements for Welding Operations

3.5.1. The contractor shall be responsible for the quality of all work performed by his welding organization.

3.5.2. All welds produced on automatic welding machines shall meet the test requirements of this standard but this shall not be construed to mean that automatic-machine operators shall be qualified as manual-welding operators.

3.5.3. Manual-welding operators shall be qualified under Section IX, Part A, of the ASME Boiler and Pressure Vessel Code, the standard qualification procedure of the American Welding Society or any other code specified by the purchaser.

3.5.4. The inspector shall have the right at any time to call for and witness the making of test specimens by any welding operator in accordance with this standard, and the expense of such tests shall be borne by the contractor.

Sec. 3.6—Welding

3.6.1. Welding of the following types shall be permitted and shall be considered equal alternatives: fusion butt welding of straight or spiral seams, resistance butt welding of straight or spiral seams, and induction butt welding.

3.6.2. Plates shall be held in the correct position. Abutting edges shall be properly prepared. Each deposited layer of welded metal in the fusion welding process shall be thoroughly cleaned before additional weld metal is applied to its surface. Finished weld bead shall be central to the seam and the finished joint shall be free from depressions, undercut edges, burrs, irregularities, and valleys. The inner surfaces of the pipe shall be free from burrs and other irregularites resulting from welding other than the normal bead necessary.

3.6.3. All welds shall have complete fusion with base metal and shall be free from cracks, oxides, slag inclusions, and gas pockets. If the automatic welding machine does not obtain a weld that will penetrate through to the inside of the pipe and protrude beyond the contour of the surface, an inside pass shall be made in the root of the groove on the inside of the pipe. Chipping out of the weld in the root of the groove will be required when deemed necessary by the inspector.

3.6.4. If welding is stopped for any reason, special care shall be taken when welding is resumed to obtain complete penetration between weld metal, plate, sheet, and weld metal previously deposited, and if flux is used it must be redistributed before work is resumed.

Sec. 3.7—Corrections to Welds

3.7.1. Welds found deficient in dimensions but not in quality shall be enlarged by additional welding after thorough cleaning of the welds and adjoining plate.

3.7.2. Welds considered by the inspector to be deficient in quality or made contrary to any mandatory provision of this standard shall be removed by chipping or melting and shall be remade.

3.7.3. In the removal of part or all of a weld by cutting or chipping, such cutting or chipping shall not extend

into the base metal beyond the depth of weld penetration. In the removal of part or all of a weld, care shall be taken not to burn or otherwise injure the base metal. After this operation the burnt metal shall be completely removed to clean, sound metal in preparation for rewelding.

Sec. 3.8—Automatic Welding

All longitudinal, spiral, and girth seams of straight pipe sections, and special sections when practicable, shall be welded with an automatic welding machine. Sample welds shall be submitted to the inspector for testing. Approval of such tests shall be required prior to welding of the pipe.

Sec. 3.9—Manual Welding

Manual welding of girth seams will be permitted on extraordinarily long straight pipe sections, consisting of more than one standard length, when agreed to by the purchaser and contractor. Manual welding of special sections and fittings will be permitted when it is impractical to use an automatic welding machine. On straight pipe sections the only manual welding permitted shall be that required in tack welding of coils and plates during the continuous pipe-making process, in making an inside pass on the inside of the pipe, in rewelding and repairing structural defects in the plate and automatic machine welds, and as otherwise permitted in this standard.

Sec. 3.10—Rounding of Sections and Sizing of Ends

If it is necessary to reshape pipe after it has been welded, reshaping shall be performed by rerolling or by pressure. Reshaping of pipe by dropping or by hammering will not be permitted. Sizing of pipe ends to come within specified end tolerances shall be permitted.

Sec. 3.11—Preparation of Ends

3.11.1. *Ends for slip joints (lap joints) for field welding.* Bell ends shall be pressed or rolled to the required shape without hammering. Spigot ends of pipe 30 in. in diameter and larger shall be shaped in or over a die. The longitudinal welds on the inside of the bell end and on the outside of the spigot end on each section of pipe shall be ground to the plate surface. The inside edge of the bell and the outside edge of the spigot end shall be scarfed or lightly ground sufficiently to remove the sharp edges or burrs in the end of the pipe sections.

3.11.2. *Plain or beveled ends for field butt welding.* Ends of pipe sections required for field butt welds either with or without backing-up strips or chill rings shall be plain or beveled.

3.11.3. *Plain ends fitted with butt straps for field welding.* Plain ends of pipe sections fitted with butt straps for field joints shall comply with the details shown on the drawings. Butt straps shall be of the same thicknesses as the corresponding pipe section, shall be of the required width, shall be rolled to fit the outside diameter, and shall be welded to the pipe section. One half of the butt strap shall be welded to the upper half of the end of the pipe section and the other half shall be welded to the lower half of the other end of the pipe section, or a complete butt strap may be fully welded to one end of each pipe section which is to be joined in the field by welding to an adjoining section, or butt straps can be furnished loose, if required. Longitudinal or spiral welds on the outside of the plain end shall be ground to

plate or sheet surface a sufficient distance from the end. The inside edge of the butt strap and the outside edge of the adjacent pipe length shall be ground or sufficiently scarfed to remove sharp edges or burrs.

3.11.4. *Ends for mechanically coupled field joints.* Ends for mechanically coupled field joints shall be as specified by the purchaser and shall be plain, grooved, or banded. The outside ends of plain-end pipe shall be free from surface defects and shall have the longitudinal or spiral welds ground to surface for a sufficient distance from the ends to permit the pipe to make a watertight joint with the coupling. Grooved or banded ends shall be prepared to fit the type of mechanical coupling to be used.

3.11.5. *Ends for riveted field joints.* Ends for riveted field joints shall be as specified by the purchaser and shall be prepared for bumped joints, butt-strap construction, or lap joints, the latter formed by using tapered pipe sections or inside and outside pipe sections. Edges at ends of pipe shall be suitably planed or bevel sheared for field calking. All rivet holes shall be accurately spaced and shall be drilled or subpunched and reamed $\frac{1}{16}$ in. larger than the nominal size of the rivet. Holes shall be free from burrs and torn or damaged edges.

3.11.6. *Bell-and-spigot ends with rubber gasket.* Bell ends shall be pressed, rolled, or fabricated from plate, sheets, or special sections to the required shape without hammering. Spigot ends shall be formed or fabricated to the required dimensions. The form of the end to retain the gasket shall be in conformance with approved drawings. Longitudinal or spiral welds on the inside of the bell end and the outside of the spigot end shall be ground to the plate surface for a distance not less than the depth of insertion of spigot end into bell end. The gasket shall conform to gasket material requirements set forth in AWWA C300. It shall be shaped for watertightness and shall be furnished by the pipe manufacturer.

3.11.7. *Plain ends fitted with flanges.* Ends to be fitted with flanges shall have the longitudinal or spiral welds on the pipe ground to plate or sheet surface for a distance from the ends to accommodate the flange.

3.11.8. *Tapered ends for driven field joints.* Ends for driven field joints shall be prepared to produce a tight joint.

Section 4—Tolerances

Sec. 4.1—Ends

The ends of each section of pipe shall be accurately measured with a steel tape and shall not exceed the tolerances set forth below, provided, however, that such tolerances do not interfere with the making of the joints.

4.1.1. For a distance of not less than 10 in. from the ends, the outside circumference of pipe with the following types of ends shall be not less than $\frac{1}{16}$ in. smaller nor more than $\frac{1}{8}$ in. greater than the outside circumference computed from the nominal outside diameter or the nominal inside diameter plus twice the nominal thickness:

a. Plain ends of slip joint (lap joint) pipe for field welding

b. Plain ends with butt straps for field welding

c. Beveled ends fitted with butt straps for field welding

d. Both ends of inside section of inside and outside pipe sections or the smaller end of tapered section for lap riveted field joints

e. Plain ends fitted with flanges.

4.1.2. Ends for mechanical couplings shall have tolerances within the limits required by the manufacturer of the type of coupling to be employed.

4.1.3. For a distance of not less than 10 in. back from the ends the inside circumference of pipe with the following types of ends shall be not less than $\frac{1}{16}$ in. smaller nor more than $\frac{1}{8}$ in. greater than the inside circumference computed from the nominal inside diameter or from the nominal outside diameter less twice the nominal thickness.

a. Ends plain or beveled for field butt welding

b. Bumped ends for riveted field joints

c. Ends for riveted field joints.

The tolerance for tapered pipe shall apply at the smaller end only.

4.1.4. The inside diameter of the bell of slip joint pipe for field welding shall be $\frac{1}{32}$—$\frac{3}{16}$ in. greater than the outside diameter of the plain end. The inside diameter of the outside section of inside and outside pipe sections or the inside diameter of the larger end of tapered sections for lap riveted field joints shall be $\frac{1}{16}$—$\frac{1}{8}$ in. greater than the outside diameter of the inside section or smaller end of the tapered section; such outside diameter shall be the nominal outside diameter or shall be equal to the nominal inside diameter plus twice the nominal thickness.

4.1.5. The out-of-roundness of pipe ends at the fabricator's plant when measured on any diameter shall be within limits consistent with the type of field joint specified and the type of corrosion protection to be employed.

4.1.6. The ends of all pipe sections shall not vary more than $\frac{1}{8}$ in. at any point from a true plane at right angles to the axis of the pipe.

Sec. 4.2—Circumference

The outside circumference of pipe 20 in. in diameter and larger shall not vary more than 0.5 per cent from the size specified, except that the circumference at ends shall be sized, if necessary, to meet the requirements of this standard. The outside circumference of pipe less than 20 in. in diameter shall not vary more than 1 per cent from the size specified.

Sec. 4.3—Straightness

Finished pipe sections shall be truly straight with walls parallel to the axis of the pipe. Any pipe section with a fault in alignment exceeding $\frac{1}{8}$ in. for each 10 ft in length from a line parallel to the axis of the pipe will be rejected.

Sec. 4.4—Length

Straight pipe sections shall not vary from the specified length by more than 2 in. Special sections shall not vary from the specified length by more than $\frac{1}{8}$ in.

Sec. 4.5—Weld Bead

The height of the outside weld bead above the contour of the plate surface shall be not more than $\frac{1}{8}$ in. Beads exceeding $\frac{1}{8}$ in. in height shall be removed by grinding or chipping. All longitudinal, spiral, and girth welds

on the inside of the pipe shall be milled, ground, or chipped down so that the height of weld bead shall be not more than $\frac{1}{16}$ in. above the contour of the plate surface. Milling, grinding, or chipping of the weld bead below the surface of the plate shall not be permitted.

Sec. 4.6—Bell-and-Spigot Ends With Rubber Gasket

The difference in circumferential measurement between the outside circumference of the spigot and the inside circumference of the bell shall be no less than 0.060 in. and no more than 0.200 in.

Section 5—Tests

Sec. 5.1—Weld Test Specimens

5.1.1. Weld test specimens shall be furnished the inspector approximately every 300 ft of pipe and shall be furnished more often if, in the judgment of the inspector, a satisfactory weld is not being made. Weld specimens may be cut from the pipe along the longitudinal seam, spiral seam, circumferential seam or from test plates welded to ends of pipe sections as may be required by the inspector. The preparation of the edges of the test plates and the welding processes, procedures, and technique shall be the same as those used in the fabrication of the pipe.

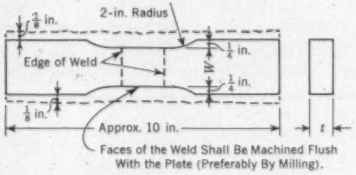

Fig. 1. Reduced-Section Tensile-Test Specimen

If coupons have been cut apart by a fusion process, the flame-cut surfaces are to be machined off as indicated. The width (W) *of the machined specimen shall be approximately 1½ in. if* t *is equal to or less than 1 in.; if* t *is greater than 1 in.,* W *shall be approximately 1 in.*

5.1.2. Tests of the specimen plates shall be made at the purchaser's expense, and such tests shall be performed at the purchaser's laboratory, at a commercial laboratory designated by the purchaser, or at the contractor's plant, if facilities are available. The contractor will be permitted to insert a patch in the pipe. Where feasible, the patch shall be welded, both inside and outside, filling the area from which the specimens are cut, except that, if specimens are cut from the end of the pipe, the ends of the pipe shall be cut off to the extent necessary.

5.1.3. The test specimen plates shall be of sufficient size to obtain the required test specimens.

5.1.4. Two etch or waste specimens, one reduced-section tensile-test specimen, one free-bend test specimen, one reverse-bend test specimen, and one nick break test specimen shall be taken from each test specimen plate. A $\frac{3}{8}$-in. clearance shall be left between specimens to permit milling and machining of specimens to size. Flame-cut edges of test specimens shall be prepared as follows:

a. Etch specimens. Each specimen shall be $\frac{1}{2}$ in. wide and shall be obtained from each end of the test specimen plate. The two cross-sectional surfaces of the welded joint specimen

shall be polished to bright, smooth surfaces. This shall be accomplished by filing and polishing with emery cloth and shall be completed with the use of emery cloth of 00 grade. If the specimens are removed by flame cutting they shall be machined, ground, or filed to a smooth surface by the removal of not less than $\frac{1}{8}$ in. of material below the flame-cut surface and they shall then be polished as above. The specimens shall then be etched in a shape and dimensions shown in Fig. 2. The free-bend test specimens shall be bent transversely to the welded joint with the wider portion of the weld surface on the outside of the bend. The bend in the specimen may be started by holding the specimen in a vise about one-third from the end, producing an initial bend at this point with hammer blows. Another bend about one-third from the other end may be produced in the same manner. The specimen with

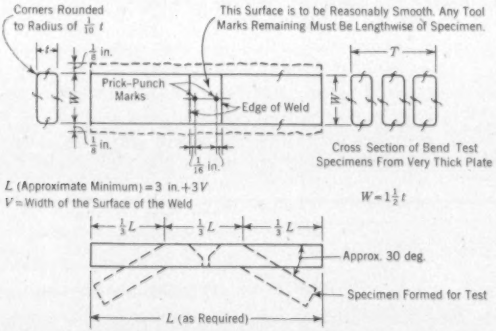
Corners Rounded to Radius of $\frac{1}{10}$ t
This Surface is to be Reasonably Smooth. Any Tool Marks Remaining Must Be Lengthwise of Specimen.
t
$\frac{1}{8}$ in.
T
W
Prick-Punch Marks
Edge of Weld
W
$\frac{1}{8}$ in.
$\frac{1}{16}$ in.
Cross Section of Bend Test Specimens From Very Thick Plate
L (Approximate Minimum) = 3 in. + 3V
V = Width of the Surface of the Weld
W = 1½ t
⅓ L
⅓ L
⅓ L
Approx. 30 deg.
Specimen Formed for Test
L (as Required)

Fig. 2. Free-Bend Test

If coupons have been cut apart by a fusion process, the flame-cut surfaces are to be machined off as indicated. The symbol "f" indicates a light finish cut; weld reinforcement is to be removed. The length (L) *of the bend specimen is immaterial provided the bend occurs at the weld.*

boiling solution of equal parts of hydrochloric acid and water for a sufficient period of time to reveal any lack of soundness that might exist at the cross-sectional surfaces of the specimen.

b. Reduced-section tensile-test specimens. Reduced-section tensile-test specimens shall be of the size and dimensions shown in Fig. 1.

c. Free-bend test specimens. Free-bend test specimens shall be of the the initial bend at each end and at atmospheric temperature is then placed as a strut in a vice or compression machine and the pressure applied gradually—that is, without shock—at the ends until failure occurs in the outside fibers of the bend specimen. When a crack is observed in the convex surface of the specimen between the edges, the specimen shall be considered to have failed and the test shall

be stopped. Cracks at the corners of the specimen shall not be considered as a failure. The appearance of small defects in the convex surface shall not be considered as a failure if their greatest dimension does not exceed $\frac{1}{16}$ in.

d. Reverse-bend test specimens. Reverse-bend test specimens shall be of the shape and dimensions as shown in Fig. 3. The reverse-bend test specimen for single-welded butt joints without a backing-up strip shall be bent around a pin or mandrel whose diameter is equal to the thickness of the specimen and through an angle of at least 30 deg.

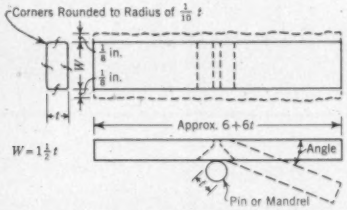

Fig. 3. Reverse-Bend Test

If coupons have been cut apart by a fusion process, the flame-cut surfaces are to be machined off as indicated. The symbol "f" indicates a light finish cut; weld reinforcement is to be removed.

e. Nick break test specimen. The nick break test specimen shall be of the shape and dimensions shown in Fig. 4. It shall be suitably supported and broken in the center of the weld by a sharp blow or blows of a hammer.

Sec. 5.2—Results of Weld Tests

The minimum requirements for the test results are given below:

5.2.1. *Reduced-section tensile test.* Yield point and ultimate tensile strength shall be not less than the minimum of the specified tensile range of the plate used.

5.2.2. *Free-bend test.* The elongation shall be measured within or across approximately the entire weld on the outside of the fibers of the test specimen and shall be at least 20 per cent. The widths of any surface crack shall be deducted.

5.2.3. *Reverse-bend test.* There shall be no defects due to lack of fusion between weld metal and plate and there shall be no cracks other than small surface cracks.

5.2.4. *Nick break test.* The fracture shall show complete penetration through the entire thickness of the weld, an absence of oxide or slag inclusions, and a degree of porosity not to exceed six gas pockets per square inch of the total area of the weld surface exposed in the fracture. The maximum dimension of any gas pocket shall not exceed $\frac{1}{16}$ in.

Sec. 5.3—Retests of Welds

If any welds fail to meet any of the test requirements, two additional test specimen plates shall be cut from the pipe section from which the original specimen plate was obtained, and retests shall be made on these additional specimens. Should any of the tests made from the second test specimen plates fail to meet the requirements, all pipe sections in the lot represented by the pipe section whose retest failed, as determined by the inspector, will be rejected. All pipe sections in this lot, other than the pipe section from which the test specimens were obtained, may be reconditioned and resubmitted for inspection. The inspector may require as many specimen plates as he desires from this lot and all tests shall meet the requirements, or all pipe sections in this lot

will be rejected. The inspector may require that the welding operator whose retest failed shall not be permitted to perform any further welding required under this standard. The contractor will be charged by the purchaser for all expenses incurred in making retests.

Sec. 5.4—Hydrostatic Tests

5.4.1. *Pipe 30 in. in diameter and larger.* Each straight pipe section and tapered section whose ends are in planes at right angles to the pipe axis shall be tested hydrostatically in a testing machine. The test pressure shall be that specified by the purchaser, but shall not exceed that determined by the following formula:

$$P = \frac{2st_1}{D}$$

in which P is the test pressure (in pounds per square inch); s is the allowable fiber stress (in pounds per square inch), which shall be equal to 85 per cent of the yield point of the specified plate; t is the wall thickness (in inches) required for the specified working water pressure; and D is the inside diameter (in inches) of straight pipe sections or the larger inside diameter of tapered sections.

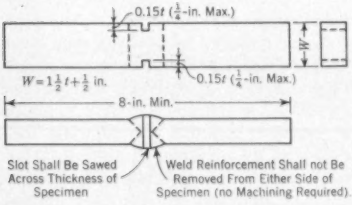
0.15t (1/4-in. Max.)
W
W=1 1/2 t+1/2 in.
0.15t (1/4-in. Max.)
8-in. Min.
Slot Shall Be Sawed Across Thickness of Specimen
Weld Reinforcement Shall not Be Removed From Either Side of Specimen (no Machining Required)

Fig. 4. Standard Bar for Nick Break Test

The specimen shall be suitably supported and broken in the center by a sharp blow or blows of a hammer.

5.4.2. *Pipe less than 30 in. in diameter.* All straight pipe less than 30 in. in diameter shall be tested at the shop to at least the hydrostatic pressures specified in Table 2 of the Appendix to this standard, and the pressures shall be maintained for not less than 5 sec.

5.4.3. *Fittings.* Fittings made in accordance with the requirements of this standard by certified welding operators from tested pipe shall not be subjected to a hydrostatic test. All fittings not fabricated from tested pipe shall be subjected to a hydrostatic test pressure specified by the purchaser but not exceeding 1½ times the working water pressure. Sections that cannot be tested in a testing machine may be prepared for testing by welding on heads, or as otherwise approved by the engineer, and after testing the ends shall be reconditioned when necessary.

5.4.4. *Test procedure.* Vents shall be provided at all high points of the pipe to prevent the formation of air pockets while the pipe is being filled, and before the application of pressure the equipment shall be inspected to see that it is tight. The required pressure shall be maintained generally for 2 min and occasionally for 5 min. While under pressure the welded seams shall be inspected for leaks and each leak shall be marked plainly. In this test no hammering shall be permitted. Any section showing more than one leak for each 5 ft of welded seam, or more than 2.5 per cent of the total length of welded seam, will be rejected. Closing leaks by means of a calking tool shall not be permitted. In sections showing less than one leak for each 5 ft of welded seam and not

more than 2.5 per cent of the total length of the welded seam, the leaks shall be repaired by chipping the weld and rewelding by hand, after which the pipe shall be retested hydrostatically. If, on retest, a pipe section shows any leaks in the welded seams it shall be rejected. Accepted pipe sections shall be stamped after test by the inspector with some legible mark of identification. In place of the inspector's stamp, the purchaser may accept a certificate from the contractor concerning these tests.

Section 6—Marking and Delivery of Pipe

Sec. 6.1—Marking

The date of manufacture and a serial number for identification shall be conspicously painted in white on the inside of each section of pipe and each special section. If the pipe is coated such marking shall be done at the shop and later transferred to the inside coating. The contractor may be required to furnish the engineer with field sketches showing where each numbered pipe or special section goes in the line, and the numbers on such sections shall correspond with those painted on the pipes and special sections.

Sec. 6.2—Delivery

Pipe sections and special sections shall be delivered in the order required by the purchaser. The transporting and handling of coated or lined pipe shall be in accordance with the purchaser's supplementary specifications.

Sec. 6.3—Finished Pipe at Delivery Destination

6.3.1. Any pipe section or special section that shows dents, kinks, abrupt changes in curvature other than specified, or injuries at the fob delivery destination may be rejected. Any pipe section or special section that has been dropped from a truck or crane prior to completion of delivery will be rejected. The contractor shall replace, at his own expense, the rejected section with an undamaged section or he may recondition the rejected section.

6.3.2. Rejected sections shall be reconditioned by rerolling or by pressure but not by hammering and shall be retested hydrostatically to the required pressure if deemed necessary by the inspector. All sections dropped from truck or crane shall be reconditioned as stated above and shall be retested hydrostatically to the required pressure.

Appendix

Sec. A1—Intermediate-Strength Steel Plate

In connection with large-diameter steel pipe, where thickness is governed by internal pressure and high water pressures exist, consideration should be given to using a higher-strength steel than those specified in Sec. 2.1.1. This may result in substantial saving in cost of the steel pipe without sacri-

TABLE 1

Dimensions, Weights, and Test Pressures for Fabricated Steel Pipe, 4–28 in. OD*

Nom. Size, OD *in.*	Wall Thickness *in.*	Weight *lb/ft*	Test Pressure *psi*	Nom. Size, OD *in.*	Wall Thickness *in.*	Weight *lb/ft*	Test Pressure *psi*
4	0.105	4.3	1,000	16	0.135	22.8	300
	0.135	5.5	1,200		0.179	30.2	400
					0.188	31.6	400
4½	0.105	4.9	900		0.239	40.2	550
	0.135	6.2	1,000		0.250	42.0	550
					0.312	52.3	700
6	0.105	6.6	600	18	0.135	25.7	250
	0.135	8.4	800		0.179	34.0	350
	0.188	11.6	1,100		0.188	35.6	350
	0.219	13.5	1,300		0.239	45.3	450
					0.250	47.3	500
6½	0.105	7.3	550		0.312	59.0	600
	0.135	9.3	700				
	0.188	12.8	1,000	20	0.135	28.6	250
	0.219	14.9	1,200		0.179	37.8	300
					0.188	39.6	350
8	0.105	8.8	450		0.239	50.4	400
	0.135	11.3	600		0.250	52.7	450
	0.179	14.9	800		0.312	65.7	550
	0.188	15.6	850		0.375	78.5	700
	0.239	19.8	1,100				
				22	0.179	41.7	300
8½	0.105	9.5	400		0.188	43.6	300
	0.135	12.2	550		0.239	55.5	400
	0.179	16.1	750		0.250	58.0	400
	0.188	16.8	750		0.312	72.3	500
	0.239	21.4	1,000		0.375	86.6	600
10	0.135	14.2	450	24	0.179	45.5	250
	0.179	18.7	650		0.188	47.6	300
	0.188	19.6	700		0.239	60.6	350
	0.239	24.9	850		0.250	63.4	350
					0.312	79.0	450
10¾	0.135	15.3	400		0.375	94.6	550
	0.179	20.2	600		0.438	110.0	650
	0.188	21.1	650		0.500	125.4	750
	0.239	26.8	800				
				26	0.179	49.3	250
12	0.135	17.1	400		0.188	51.6	250
	0.179	22.5	550		0.239	65.7	300
	0.188	23.6	550		0.250	68.7	350
	0.239	30.0	700		0.312	85.7	400
					0.375	102.6	500
					0.438	119.4	600
					0.500	136.1	700
12¾	0.135	18.1	350	28	0.179	53.1	250
	0.179	24.0	500		0.188	55.6	250
	0.188	25.1	500		0.239	70.8	300
	0.239	31.9	650		0.250	74.0	300
					0.312	92.4	400
14	0.135	19.9	350		0.375	110.6	450
	0.179	26.4	450		0.438	128.7	550
	0.188	27.6	450		0.500	146.8	650
	0.239	35.1	600				

* Other diameters and wall thicknesses can be furnished by some manufacturers.

ficing quality or security. For this purpose, the following specification is recommended:

Steel plate shall comply with the chemical and physical requirements of API Specifications for High Test Line Pipe, Standard 5LX, Grade X42, and shall conform to the applicable requirements of the latest revision of ASTM A6 (Delivery of Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use).

Sec. A2—Physical Data

A2.1. Dimensions, weights, and test pressures for fabricated steel pipe of sizes 4–28 in. (OD) are given in Table 1.

A2.2. Dimensions and weights of fabricated steel pipe of sizes 30–96 in. (ID) are given in Table 2.

TABLE 2

*Dimensions and Weights for Fabricated Steel Pipe, 30–96 in. ID**

Nom. Size, ID *in.*	Wall Thickness—*in.*									
	0.188	0.250	0.312	0.375	0.438	0.500	0.625	0.750	0.875	1.000
	Weight—*lb/ft*									
30	62.2	83.1	103.9	124.6	145.4	166.1				
32	66.8	88.9	110.8	132.9	154.9	177.0				
34	71.0	94.4	117.6	141.1	164.5	187.9				
36	75.5	100.1	124.8	149.6	174.5	199.2	249.3			
38	79.9	105.7	131.7	157.9	183.8	210.2	262.9			
40	82.4	110.1	137.5	164.9	192.0	220.0	275.9			
42	86.5	115.6	144.3	173.1	201.7	230.9	289.5			
45		123.8	154.6	185.3	216.0	247.2	309.8			
48		132.3	165.6	198.5	231.4	264.1	330.2	396.3		
51		140.6	175.9	210.9	245.7	280.5	350.6	420.7		
54		149.1	186.2	223.2	260.0	296.8	371.0	446.2		
57		157.4	196.5	235.5	274.4	313.1	391.3	470.6		
60		165.6	206.8	247.8	288.7	329.5	411.7	495.1	578.8	662.8
63		174.3	217.1	260.1	303.0	345.8	432.1	519.5	607.3	695.4
66		182.6	227.4	272.4	317.4	362.2	452.5	544.0	635.8	728.0
69		191.3	238.2	285.4	332.5	379.4	474.0	568.4	664.4	758.8
72		199.6	248.5	297.8	346.9	395.8	494.4	592.9	692.9	791.3
75		207.9	258.8	310.1	361.2	412.2	514.8	617.3	721.4	823.8
78		214.6	267.9	320.9	373.8	426.5	534.0	640.2	748.1	856.3
81		223.4	278.8	334.0	389.0	443.9	554.3	666.2	778.5	891.0
84		231.6	289.1	346.3	403.4	460.2	574.7	690.7	807.0	923.6
87		239.9	299.4	358.6	417.7	476.5	595.1	715.1	835.5	956.2
90		248.1	309.7	371.0	432.0	492.9	615.5	739.6	864.0	988.8
93		257.0	319.9	383.3	446.4	509.2	635.8	764.0	892.6	1,021.0
96		265.3	329.4	395.6	460.7	525.6	656.2	788.5	921.1	1,054.0

* Other diameters and wall thicknesses can be furnished by some manufacturers. Weights are the theoretical weight plus overweight tolerance, which varies from about 1.75 per cent for pipe $\frac{1}{4}$ in. thick to a maximum of 4.5 per cent for pipe 3/16 in. thick, or an average of approximately 2.5 per cent.

2P-25C-12/60

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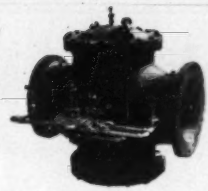

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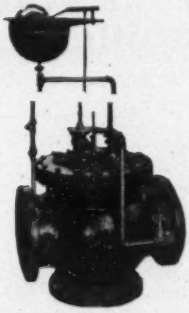

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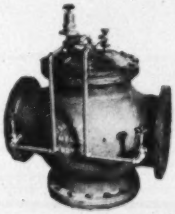

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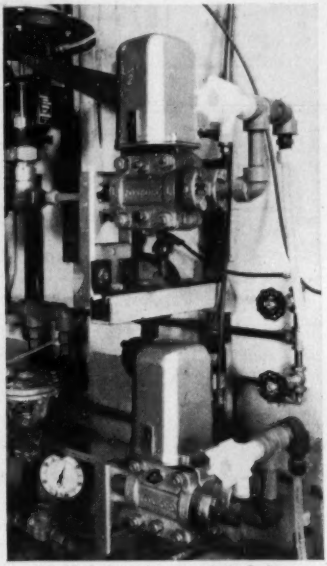

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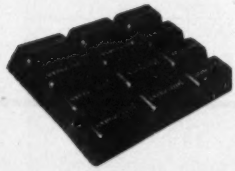

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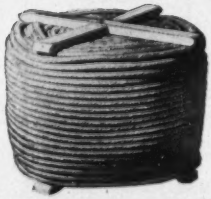

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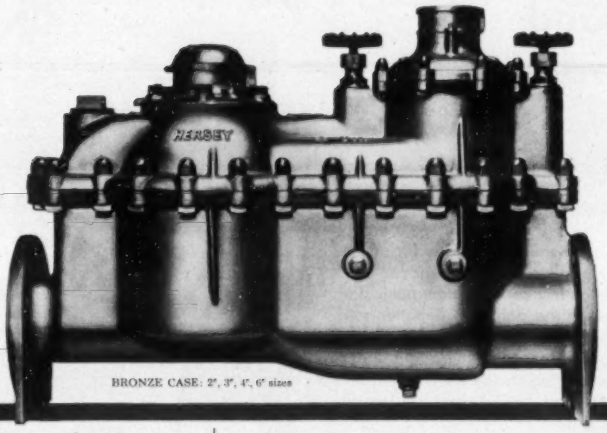

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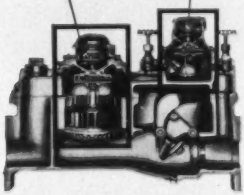

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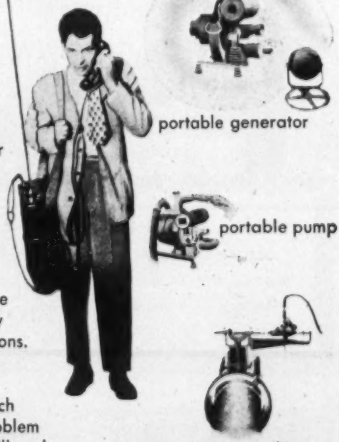

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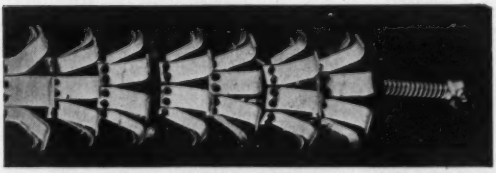

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